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WATER RIGHTS ASSESSMENT FOR BEAVER CREEK NATIONAL WILD RIVER ALASKA

JUNE 1987

BUREAU OF LAND MANAGEMENT SERVICE CENTER
DIVISION OF RESOURCES
LAKEWOOD, COLORADO

THE CALL OF THE WILD

Have you gazed on naked grandeur where
there's nothing else to gaze on,
Set pieces and drop-curtain scenes galore,
Big mountains heaved to heaven, which the
blinding sunsets blazon,
Black canyons where the rapids rip and roar?
Have you swept the visioned valley with the
green stream streaking through it,
Searched the Vastness for a something you
have lost?
Have you strung your soul to silence? Then
for God's sake go and do it;
Hear the challenge, learn the lesson, pay the
cost.

Have you wandered in the wilderness, the sage-
brush desolation,
The bunch-grass levels where the cattle
graze?
Have you whistled bits of rag-time at the end
of all creation,
And learned to know the desert's little ways?
Have you camped upon the foothills, have you
galloped o'er the ranges,
Have you roamed the arid sun-lands through
and through?
Have you chummed up with the mesa? Do
you know its moods and changes?
Then listen to the Wild--it's calling you.

Have you known the Great White Silence, not
a snow-gemmed twig aquiver?
(Eternal truths that shame our soothing
lies.)
Have you broken trail on snowshoes? mushed
your huskies up the river,
Dared the unknown, led the way, and
clutched the prize?
Have you marked the map's void spaces,
mingled with the mongrel races,
Felt the savage strength of brute in every
thew?
And though grim as hell the worst is, can you
round it off with curses?
Then hearken to the Wild--it's wanting
you.

Have you suffered, starved and triumphed,
groveled down, yet grasped at glory,
Grown bigger in the bigness of the whole?
"Done things" just for the doing, letting bab-
blers tell the story,
Seeing through the nice veneer the naked
soul?
Have you seen God in His splendors, heard the
text that nature renders?
(You'll never hear it in the family pew.)
The simple things, the true things, the silent
men who do things--
Then listen to the Wild--it's calling you.

They have cradled you in custom, they have
primed you with their preaching,
They have soaked you in convention through
and through;
They have put you in a showcase; you're a
credit to their teaching--
But can't you hear the Wild?--it's calling
you.
Let us probe the silent places, let us seek what
luck betide us;
Let us journey to a lonely land I know.
There's a whisper on the night-wind, there's
a star agleam to guide us,
And the Wild is calling, calling . . . let us
go.

From "The Spell of the Yukon," Robert Service, 1933.
Dodd, Mead & Co.

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WATER RIGHTS ASSESSMENT FOR BEAVER CREEK NATIONAL WILD RIVER, ALASKA

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June 1987

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Beaver Creek

EXECUTIVE SUMMARY

Beaver Creek, a tributary to the Yukon River, was designated a National Wild River by Congress December 2, 1980. Inclusion into the Wild and Scenic Rivers System was based on primitiveness, exceptional grayling fishing, exceptional aesthetic qualities, abundant wildlife in the river corridor, outstanding novice and family canoeing opportunities, good water quality, and the ability of the river to provide outstanding recreational opportunities.

Based on the language in the Wild and Scenic Rivers Act (P.L. 90-542) and existing case law, we believe that a Federal reserved water right, sufficient to serve the purposes of the wild river designation, was created on Beaver Creek on the date Congress designated Beaver Creek a National Wild River.

The goal of this project was to identify the minimum amount of water necessary to preserve and protect the natural values of the Beaver Creek National Wild River and its immediate corridor environs and to recommend a legal vehicle through which those recommended flow regimes can be recognized and protected. In some cases, minimum required flows are somewhat less than "natural" or "optimum" flow levels.

River resource values are nearly all dependent to some degree on river flow levels. Results of literature reviews and a field survey were used to establish relationships between resource values and flow levels. The annual Beaver Creek flow regime was stratified into three distinct seasons:

- Winter base flows (November-April)

- Summer-fall seasonal flows (July-October)

- Spring seasonal flows (May-June)

Winter base flows are key to over-winter survival of arctic grayling. Summer-fall seasonal flows directly influence recreational boating conditions (velocities, depths, widths) and fishery habitat (wetted perimeter, velocities). Spring seasonal flows influence key channel morphology features such

as active channel width, gravel bar size, pool depth, sediment size, and the frequency and size of sloughs and oxbows. Morphological features, in turn, contribute to fishery habitat, camping quality, visual/aesthetic qualities, and boating conditions.

Recommended winter instream flows are equivalent to the existing natural base flows of that period. Winter flows are extremely low and support a few critical pools used by over-wintering grayling. Even small reductions in winter period flows could be highly detrimental to grayling survival. Thus, we recommend no reductions in flow during the November-April period.

Recommended instream flows during the spring high-flow period are equivalent to 80 percent of the natural instantaneous flows of Beaver Creek during this period. These flows represent a 20 percent reduction in the Beaver Creek flood-frequency relationship. Peak flow reductions greater than 20 percent would, in our judgment, adversely affect wild river values, such as pools, ground bars, and sloughs, dependent upon stream channel morphology.

Instream flows recommended for the summer-fall period are 90 percent of the mean monthly flow or 90 percent of the instantaneous flow, whichever is less. Flow reductions in excess of recommended values would have unacceptable adverse effects on recreational experiences on the river. In particular, the number of incidents requiring boat portaging would become unacceptably large and float times would become excessively long. Reductions in perimeter greater than that produced by a 10 percent flow reduction would significantly decrease pool depths, reduce grayling food production, cause crowding, and adversely affect habitat for grayling fry.

As of the date of this report, there are no adjudicated water rights on the main stem of Beaver Creek. Through recent legislative and policy initiatives, the State of Alaska has evidenced its dedication to the protection of the natural hydrologic values of the State. The timing is appropriate to negotiate an instream water right for the Beaver Creek National Wild River. We recommend that BLM promptly submit an instream flow water

right application through the U.S. Department of Justice to the Alaska Department of Natural Resources. This application (a draft of which is included as Appendix A) will not affirm a Federal reserved water right. The application is for a state-adjudicated instream flow reservation and contains a provision that the flow reservation be subjected to a limited review under the State's 10-year review procedure.

The project team also recommends that BLM file an instream flow reservation application with the Alaska DNR to protect recreational values of lower Nome Creek. Nome Creek is used as an ingress access route and "put-in" location by Beaver Creek float parties. The application should quantify the amount of water needed in Nome Creek to provide an acceptable float experience between all reasonable "put-in" locations and the confluence of Nome and Beaver Creeks.

INTRODUCTION

Beaver Creek was first studied in 1973 for possible addition to the National Wild and Scenic Rivers System (USDI, 1973). An environmental impact statement was subsequently prepared and recommended classification of the upper 135 miles of Beaver Creek as a National Wild River.

Beaver Creek was designated a National Wild River on December 2, 1980, when Congress amended the Wild and Scenic Rivers Act (P.L. 90-542) as part of the Alaska National Interest Lands Conservation Act (P.L. 96-487). By classifying Beaver Creek as "wild," Congress mandated that Beaver Creek National Wild River shall be managed as a river corridor to be free of water impoundments and generally inaccessible except by trail, with watersheds and shorelines in primitive condition and waters unpolluted. As a national wild river, Beaver Creek is to represent, now and in the future, vestiges of primitive America.

The River Management Plan (USDI, 1983) for the Beaver Creek National Wild River includes the following management action:

> "Action Item 5.1 - Water Rights: A reservation of minimum water flows sufficient for public recreation and to support the values for which the area was designated will be determined in cooperation with the Alaska Department of Natural Resources, Division of Land and Water Management."

The Wild and Scenic Rivers Act (P.L. 90-542) provides that

> "Certain selected rivers of the Nation, which with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the enjoyment of present and future generations."

and that

> "Designation of any stream or portion thereof as a national wild, scenic, or recreational river area shall not be construed as a reservation of the waters of such streams for purposes other than those specified in this Act, or in quantities greater than necessary to accomplish these purposes."

This language, coupled with a court created legal axiom called the reserved rights doctrine, vests in the United States of America a water right to a certain quantity of instream flow in any river that becomes a component of the National Wild and Scenic Rivers System. A reserved water right is only effective to set aside water that is unappropriated under state law at the time of the reservation. In the case of Beaver Creek the reservation was created on December 2, 1980.

It is the current policy of BLM (BLM Manual Section 7250) to assert Federal reserved water rights for designated wild, scenic, or recreational rivers under BLM management responsibility. Manual Section 7250 states that wild and scenic river designation does not automatically reserve the entire unappropriated flow of the river and that flow determinations, related to the minimum amount of water necessary to fulfill the primary purpose of the reservation, must be made on a case-by-case basis.

In accordance with the above policies and authorities, the BLM Service Center was asked by the BLM Alaska State Office and Fairbanks District in April, 1985 to plan and implement a water rights quantification project for Beaver Creek.

Beaver Creek, a tributary to the Yukon River, is located in the White Mountains of interior Alaska (Figure 1). The designated wild river segment begins in the headwaters of Beaver Creek approximately 50 miles northeast of Fairbanks, Alaska. The designated river segment is 127 miles long. For the remainder of its 303-mile total length, Beaver Creek flows through the Yukon Flats National Wildlife Refuge. The project area is defined as Beaver Creek, including its floodplain, between Wild River Miles (WRM) 0 and 111, which is that portion of the Beaver Creek National Wild River within the White Mountains National Recreation Area.

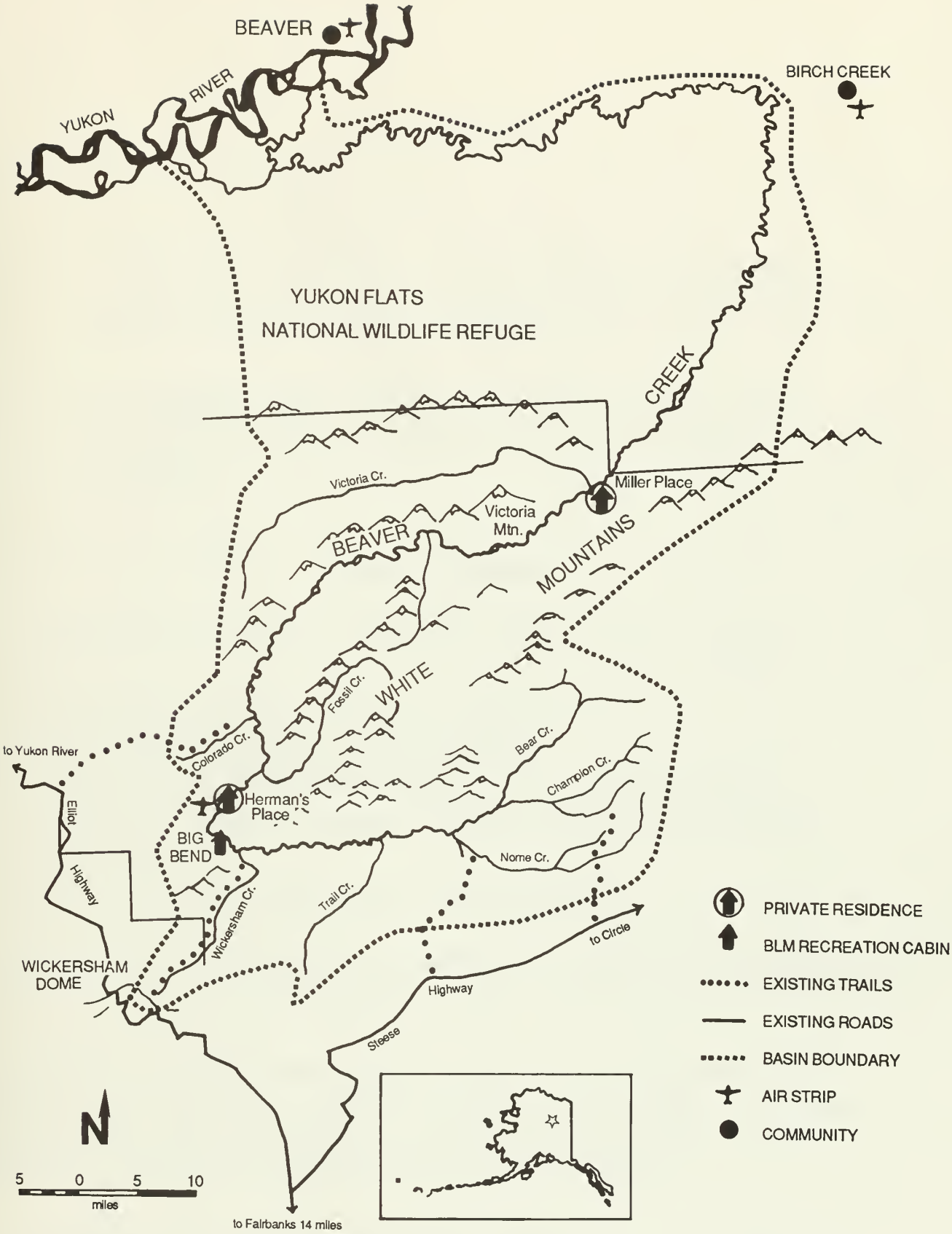

Figure 1. Location map (River Mile 0.0 is immediately below the confluence of Bear and Champion Creeks).

PROJECT OBJECTIVES

The objectives of the project are:

1. To determine the minimum quantity of water necessary to protect those natural values of Beaver Creek that made it a component of the National Wild and Scenic Rivers System.

2. To recommend a legal vehicle through which those flow regimes necessary to sustain the natural values of Beaver Creek can be protected.

APPROACH AND METHODS

The following individuals conducted the water rights assessment:

- Lou Carufel (Steese-White Mountains District Office)
- Bill Jackson (Hydrologist, Service Center)
- Tony Martinez (Water Rights Specialist, Colorado State Office)
- Bo Shelby (Associate Professor of Forest Recreation, Oregon State University)
- Bruce Van Haveren (Team Leader, Service Center)

In addition, Ron Huntsinger and Tom Dew represented the Alaska State Office and Yukon Resource Area, respectively.

Literature reviews were conducted during January to May 1986 and presented by team members at the first team meeting in June 1986. During June to July, team members interviewed various professional contacts in their respective disciplines to supplement the literature reviews.

Existing color aerial photography was available for most of the wild river corridor, with the exception of approximately 12 river miles. This was flown in June 1986 to give complete coverage of the project area. Low-level aerial video footage of the wild river corridor from River Mile 0 to the

confluence of Beaver and Victoria Creeks was also obtained by the Yukon Resource Area in June 1986. This coverage was used by the team to stratify homogeneous reaches of the project area and to preselect sampling sites.

The team conducted a field survey during July 27 to August 3, 1986. Sampling locations are shown in Table 1.

The purpose of the field survey was to:

1. Determine the natural flow regime and channel characteristics of Beaver Creek at selected points along the wild river corridor.

2. Ascertain recreational values in relation to streamflow levels.

3. Collect fishery habitat information from Beaver Creek and its tributaries.

Seven discharge measurements were made and 10 channel cross-section surveys conducted to obtain channel hydraulics information (Figures 2 and 3).

Table 1. Sampling site descriptions

		Wild River Mile
Q_1 - NE 1/4, SW 1/4, S 20, T7N, R4E	Confluence of Bear and Champion Creeks	0
Q_2 - 65° 23' N 147° 08' W	Beaver Creek above Nome Creek Confluence	6
Q_3 - 65° 24' N 147° 10' W	Beaver Creek below Nome Creek	7.5
Q_4 - SE 1/4 NE 1/4, S32, T7N, R1W	Beaver Creek split channel below Borealis Cabin	33.5
Q_5 - NE 1/4 NW 1/4, S31, T7N, R1W	Beaver Creek above Big Bend	35
Q_6 - NE 1/4 SW 1/4, S22, T10N, RIE	Beaver Creek below Lost Horizon Creek (Meandering Reach)	68.5
Q_7 - SE 1/4 SW 1/4, S2, T11N, R5E	Beaver Creek above Victoria Creek	109.5
G1 - NE 1/4, SW 1/4, S 20, T7N, R4E	Confluence of Bear and Champion Creek	0.0
G2 - 65° 23' N 147° 08' W	Beaver Creek above Nome Creek confluence	6
G3 - 65° 23' N 147° 08' W	Beaver Creek above Nome Creek confluence	6
G4 - 65° 24' N 147° 19' W	Beaver Creek below O'Brien Creek	12.5
G5 - 65° 22.5' N 147° 23' W	Beaver Creek below Trail Creek (pool)	17
G6 - 65° 22.5' N 147° 23' W	Beaver Creek below Trail Creek (riffle)	17
G7 - SW 1/4 SW 1/4 S 16, T7N, R1W	Beaver Creek above Herman's place	39
G8 - SW 1/4 NW 1/4 S6 T10N, R2E	Beaver Creek split channel below Serpentine slide (left side)	74
G9 - SW 1/4 NW 1/4 S6 T10N, R2E	Beaver Creek split channel below Serpentine slide (right side)	74
G10 - SE 1/4 NE 1/4 S1, TION, R2E	Beaver Creek above Dead Moose Rock	81

Figure 2. Stream gaging was done using a wading rod and Price Current Meter. Cross section profiles were surveyed using rod and hand level techniques.

Figure 3. Where depths were too great for wading, measurements were made from a boat.

LEGAL ANALYSIS AND RECOMMENDATION

The Existence of a Reserved Water Right

The United States Supreme Court enunciated the following definition of a reserved water right:

> "This Court has long held that when the Federal Government withdraws its land from the public domain and reserves it for a Federal purpose, the Government, by implication, reserves appurtenant water then unappropriated to the extent needed to accomplish the purpose of the reservation. In so doing the United States acquires a reserved right in unappropriated water which vests on the date of the reservation and is superior to the rights of future appropriators. Reservation of water rights is empowered by the Commerce Clause, Art. I, SS 8, which permits Federal regulation of navigable streams, and the Property Clause, Art. IV, SS 3, which permits Federal regulation of Federal lands. The doctrine applies to Indian reservations and other Federal enclaves, encompassing water rights in navigable and non-navigable streams." (Caeppart v. U.S. - 426 U.S. at 138, 96 S.Ct. at 2069; citations omitted).

The Wild and Scenic Rivers Act (P.L. 90-542) expressly recognizes the existence of reserved water rights. "Sec. 13(c) Designation of any stream or portion thereof as a national wild, scenic, or recreational river area shall not be construed as a reservation of the waters of such streams for purposes other than those specified in this Act, or in quantities greater than necessary to accomplish these purposes."

Given the language of the Wild and Scenic Rivers Act and the existing case law, a reserved water right was created on Beaver Creek as of December 2, 1980, the date Congress designated Beaver Creek as a component of the National Wild and Scenic Rivers System.

The Quantity of Water Reserved

The language of the Caeppart case cited above was refined by the court in United States v. New Mexico 438 U.S. at 700, 702, 98 S.Ct. at 3014, 3015 (1978).

> "Where water is necessary to fulfill the very purposes for which a Federal reservation was created, it is reasonable to conclude, even in the face of Congress' express deference to state water law in other areas, that the United States intended to reserve the necessary water. Where water is only valuable for a secondary use of the reservation, however, there arises the contrary inference that Congress intended, consistent with its other views, that the United States would acquire water in the same manner as any other public or private appropriator."

The reservation language of the Wild and Scenic Rivers Act is concise. The reservation of water is express. The Wild and Scenic River Act (the Act) states:

> "(b) It is hereby declared to be the policy of the United States that certain selected rivers of the Nation, which with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the enjoyment of present and future generations. The Congress declares that the established national policy of dam and other construction at appropriate sections of the rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections thereof in their free-flowing condition to protect the water quality of such rivers and to fulfill other vital national conservation purposes."

"(c) The purpose of this Act is to implement this policy. . ."

To be included in the national Wild and Scenic Rivers system, a river must be 1) free flowing and 2) possess one or more of the outstandingly remarkable values enumerated by the Wild and Scenic Rivers Act. The Act's stated purpose is to protect these rivers and their immediate environments for the enjoyment of present and future generations.

The goal of the project was therefore:

To identify that minimal amount of water necessary to preserve and protect the natural values of Beaver Creek and its immediate environs as set out in this report (with a special focus on the purposes of designation) without which preservation/protection of river values would be impossible.

The technical and scientific interpretation of mandates in the Wild and Scenic Rivers Act is described below. The Team defined those hydrologic characteristics which created and maintain Beaver Creek with a special emphasis on the outstanding recreation values and free flowing condition which made it eligible for the national system. Certainly, the natural flows would be adequate to serve these purposes.

The scientific challenge of the Team was to take the hydrologic characteristics of Beaver Creek as defined and determine whether or not flows less than the natural flows would preserve/ protect the natural characteristics of the stream and its related values. The recommended flow rates are found in Tables 18 and 19 and the projected effects of flow reductions summarized in Table 20.

Mechanisms for Protection

The existence of a reserved water right has frequently been treated by Federal agencies as a legal panacea. This approach has been met with strong opposition by the various states. We believe there are opportunities to protect Federal interests in water resources without resorting to a strict

reserved water right analysis. For purposes of this study and in the interest of comity, we are filing for the state water permit without waiving any Federal claims to a reserved water right in Beaver Creek.

A recent Colorado District Court case recognized the existence of reserved water rights in wilderness areas, but enunciated the premise that confrontational assertions of reserved water rights in derogation of state law is not necessarily the only way of protecting wilderness values associated with water. In Sierra Club v. Block 622 F. Sup. 842 Dist. Ct. CO (1985) Judge Kane found:

> "To begin with, the Wilderness Act unequivocally imposes certain duties on the part of agencies and officials administering the wilderness areas. Sections 1131(a) and 1133(b) require that the wilderness character of these areas be protected and preserved. Further, Congress stated that these areas shall be administered 'for the use and enjoyment of the American people in such a manner as will leave them unimpaired for future use and enjoyment as wilderness...' 16 U.S.C. S 1131(a). Finally, S 1133(b) mandates that the 'wilderness areas shall be devoted to the public purposes of recreational, scenic, scientific, educational, conservation, and historical use' and that the agencies charged with administering the wilderness areas shall administer the areas for these purposes."

These mandates evince Congress' intent to impose a duty on the administering agencies to protect and preserve all wilderness resources, including water. Thus, there is a general duty under the Wilderness Act to protect and preserve wilderness water resources. There is, however, no specific statutory duty to claim reserved water rights in the wilderness areas even though Congress impliedly reserved such rights in order to effectuate the purposes of the Act, as discussed above.

Judge Kane was emphatic on the point that regardless of the mechanism developed, the national interests involved had to be protected:

> "Now that the issue of whether reserved water rights exist in these areas has been resolved, it is necessary to give Federal defendants the opportunity to consider further the usefulness of these rights in complying with their statutory duty to protect wilderness water resources. These Federal defendants are required to meet clear statutory obligations. How they meet this responsibility is a matter left to their discretion. Whether they must meet this responsibility is no longer subject to dispute. In remanding this action to the Federal defendants, I order them to come forward with a memorandum explaining their analysis, final decision, and plan to comply with their statutory obligations regarding protection and preservation of wilderness water resources."

Reading Judge Kane's decision broadly, the mechanism through which the hydrologic characteristics necessary to sustain an area of national significance are protected may not be as important as the final effect. The study team, therefore, examined several protection scenarios.

The present demand for water out of Beaver Creek is diminutive. There are no adjudicated rights out of the main stem. The rights adjudicated in the tributaries are found in Table 2. These water rights are for placer mining. Not only are the quantities included diminutive, the use of water for placer mining is virtually nonconsumptive. There is little real effect on Beaver Creek streamflow.

Table 2. Adjudicated water rights in Beaver Creek tributaries

Stream Name	Adjudicated Amount	Purpose	Priority Date
Quartz Creek/Bear Creek	3 cfs	Placer Mining	6/25/82
Nome Creek/Moose Creek	3 cfs	"	4/11/80
Nome Creek/Moose Creek	500 GPM (1.1 cfs)	"	6/3/83
Nome Creek/Moose Creek	1900 GPM (4.2 cfs)	"	4/12/84
Nome Creek	600,000 GPD (0.9 cfs)	"	3/14/80
Sumner Creek	3 cfs	"	7/30/81
Champion Creek	5000 GPD (0.008 cfs)	"	5/11/83
Little Champion Creek	4 cfs	"	11/1/78

The opportunity exists to develop a mechanism which could protect the national interests on Beaver Creek, leave private rights unaffected, and preserve state planning latitudes and sovereignty.

The following alternatives offer solutions for legally securing instream flow rights to Beaver Creek water:

Alt. 1. State instream flow reservation

Alt. 2. Federal reserved water right

Alt. 3. State-Federal hybrid water right

Alternative 1
State Instream Flow Reservation

The BLM could file an application for a water right in strict compliance with Alaska law. Under Alaska Statute 46.15.145, instream flow reservations may be made for the following uses:

1. Protection of fish and wildlife habitat, migration, and propagation
2. Recreation and parks
3. Navigation and transportation
4. Sanitation and water quality

The amendments passed in 1980 to the Alaska Water Use Act provide an opportunity through which private parties as well as public entities can apply to the Alaska Department of Natural Resources for reservations of water for instream flow purposes. The amendments provide for the quantification of instream uses, establishment of a priority date, and recognition under the Alaska water right administration system through the issuance of a Certificate of Reservation.

There are some substantial drawbacks to this alternative. We are most concerned with AS 46.15.145(f) which states:

> "(f) At least once each 10 years the commissioner shall review each reservation under this section to determine whether the purpose described in (a) of this section for which the certificate reserving water was issued and the findings described in (c) of this section still apply to the reservation. If the commissioner determines that the purpose or part or all of the findings no longer apply to the reservation, he may revoke or modify the certificate reserving the water in accordance with AS 46.15.140(b) (SS 7 ch 84 SLA 1980)."

This provision is potentially incompatible with the fundamental tenet of the Wild and Scenic Rivers Act: "to preserve and protect the resource for the benefit of present and future generations." The latitude to limit the right to flows less than the predetermined minimal amount necessary to satisfy the reservation or revoke the right renders the Federal position very tenuous.

Alternative 2
Federal Reserved Water Right

There is a clear basis for the assertion of a Federal reserved water right. A reserved water right is effective in setting aside any water, necessary to fulfill the purposes of the reservation, which is unappropriated as of the date of the reservation. It is certain that, with the diminutive demands for water out of Beaver Creek, there would be sufficient supplies to satisfy a reserved water right...even with a 1986 priority date. A reserved

water right does not have to conform with state law. In states where certain Federal uses of water for instream flows for various purposes, are not recognized, a reserved water right may be the only avenue for protecting instream flow values on the public lands.

The existence of an instream flow law in Alaska represents a significant commitment by the State of Alaska to protect its water-related natural resources. Federal policy suggests that to the greatest extent possible, the various Federal agencies should comply with state water law. Judge Kane's ruling in Sierra Club v. Block provides Federal agencies with some latitude to seek creative solutions. We should, therefore, make every effort to design a right which is compatible with state law and provides legal protection for the natural values of Beaver Creek. In the event that an agreement cannot be reached between the Federal government and the State of Alaska, then the assertion of a reserved water right is still a viable alternative.

Alternative 3
State-Federal Hybrid Water Right

The Alaskan instream flow law is fairly broad. The statute allows for the allocation of water for such purposes as the protection of fish and wildlife habitat, recreation, navigation and the protection of water quality. The natural values identified by Congress in setting aside Beaver Creek as a component of the National Wild and Scenic Rivers system are remarkably similar to the purposes recognized under the Alaskan instream flow statute. Alaskan law also allows the right to vest in and be protected by the United States. The only tangible drawback to Alaska's instream flow law, for purposes of a component of the National Wild and Scenic Rivers system only, is that the right can be reviewed at any time and must be reviewed at least every 10 years. If the right can be reviewed by the State, it can be limited or revoked.

To insure that the resource values of Beaver Creek are adequately protected, a provision is included in the water right application (included in Appendix A) which would fix the quantity of water decreed to the BLM and limit State review. The "limited review" provision is the foundation of this preferred alternative.

The hybridization of Alaska State law with the certainty of a fixed Federal right to a specific quantity of water has many advantages. The long-term protection of natural values utilizing administrative mechanisms familiar to the State provides the State a final determination of the quantity of water necessary to satisfy the instream flow reservation. There remains water available for appropriation. The state may comfortably allocate the water resources and the BLM is afforded a flow which will protect the natural values of Beaver Creek.

The significance of a fixed quantification to the State of Alaska is set out in the following publication by the Alaska Department of Natural Resources:

"WHY ARE WE CONCERNED ABOUT FEDERAL RESERVED WATER RIGHTS?"

- Because Federal reserved water rights are unquantified, DNR does not know how much water is needed or used for the primary purposes of Federal land withdrawals in Alaska. Because the unappropriated water available from a water source and the amount of water reserved by a Federal withdrawal is unknown, water resources cannot be effectively managed.

- For DNR to effectively manage and allocate the state's water and adjudicate water rights, it is necessary to have the Federal reserved water rights in Alaska inventoried and quantified by the appropriate Federal land management agencies in cooperation with the State of Alaska. The state can then integrate Federal reserved water rights with state administratively adjudicated water rights and manage water sources with greater certainty.

We believe that it is necessary to promptly adjudicate the Beaver Creek instream flow application. The State of Alaska has evidenced its dedication to the protection of the natural hydrologic values of the State through the passage of its instream flow law. As of the date of this report, there are no adjudicated water rights on the main stem of Beaver Creek. At some later date when there are more filings on Beaver Creek and the spirit that inspired Alaska's instream flow law has dimmed, the State may be less inclined to negotiate an agreement which fairly addresses the natural values of the area and more inclined to litigate the human equities of the situation.

Recommendation

The enclosed water right application (Appendix A) should be submitted to the Alaska Department of Natural Resources. Special attention should be given the language asserting that the water right is fixed and subject to limited review. If this clause is not accepted by the State, the matter must be resolved through the courts at the earliest possible opportunity to avoid the accumulation of equities and to provide protection to a significant natural resource.

RESOURCE VALUES

All river segments included in the National Wild and Scenic Rivers System received their designation based on specific river resource values or conservation purposes. To ascertain these values and purposes for Beaver Creek, we reviewed the original BOR study report (USDI, 1973).

The following river resource values were found by the BOR study team to be significant:

- primitiveness ("virtually no signs of man")
- exceptional grayling fishing
- exceptional aesthetic qualities
- abundant wildlife along the river
- outstanding novice or family canoeing opportunities
- outstandingly remarkable recreational opportunity

The Final Environmental Statement for the proposed Beaver Creek National Wild River (USDI, 1974) included water quality as an additional, significant river resource value. This is supported by the original BOR study report, which cited overall good water quality, with water from Beaver Creek and its tributaries being used without treatment for drinking and cooking purposes by visitors.

Each of the identified river resource values are dependent to some degree on river flow level. The wild river values are described qualitatively and quantitatively in this report. Their relationships to synthesized hydrologic variables are discussed in the section on Instream Flow Analysis and Recommendation. The approach we have used to develop an instream flow recommendation is shown conceptually in Figure 4. For sake of analysis, the wild river values were considered to be either low-flow dependent or high-flow (channel morphology) dependent. Measurable parameters representing the key recreational and fish habitat resource values are shown in Figure 4. Recreational and fishery habitat criteria are discussed in detail below.

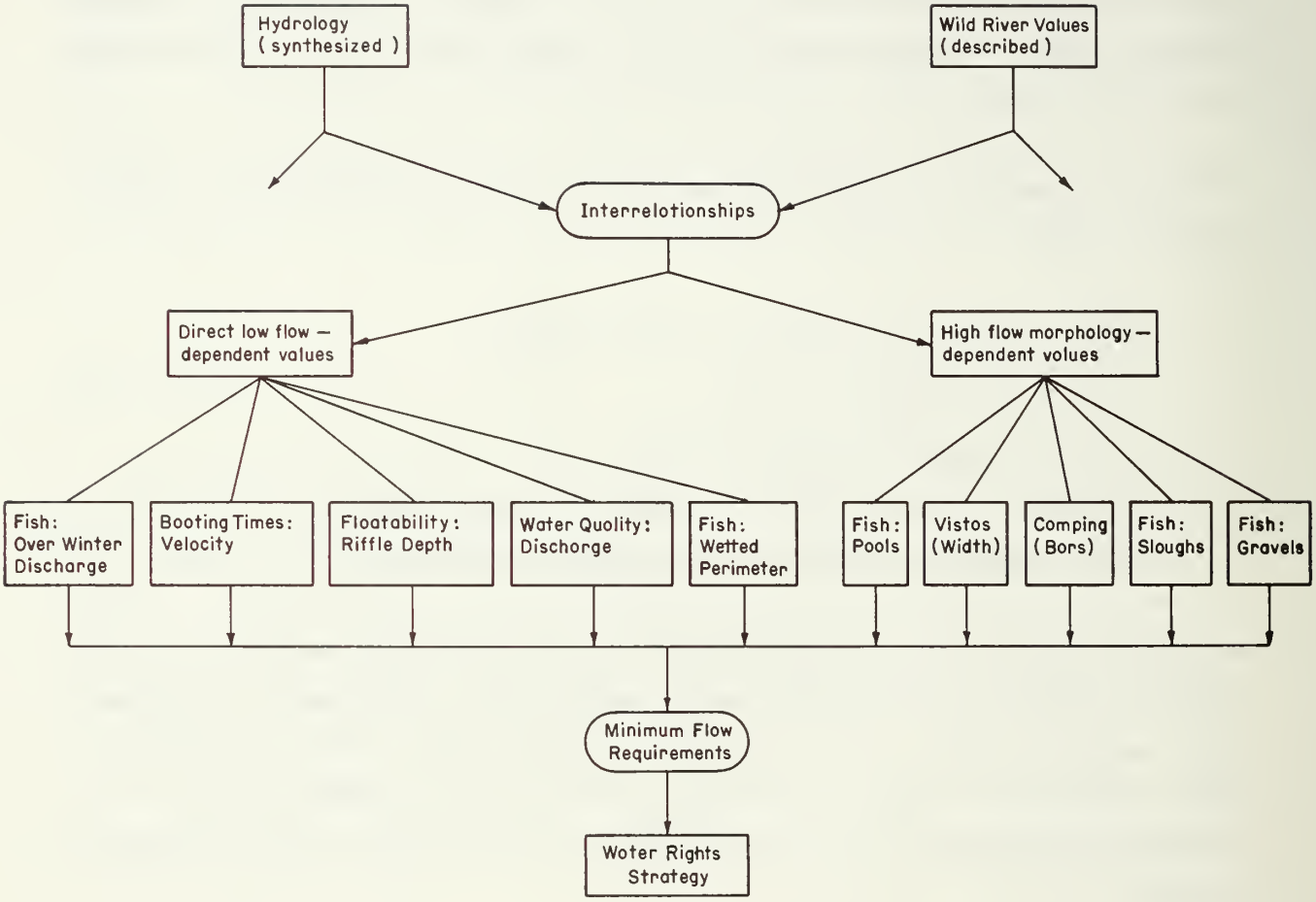

Figure 4. The instream flow quantification process.

Recreation Resource Values

Resource management decisions, including those related to instream flows, have both descriptive and evaluative components. Descriptive information provides objective information about resource characteristics. It includes information about management alternatives (management parameters) and their effect on resource conditions (impact parameters). Descriptive information regarding instream flows, for example, might show how different amounts of water (released from a dam or left after mining extractions) affect size and number of pools, size and number of rapids, necessity for and length of portages, navigability by different craft, etc.

By themselves, descriptive data only show what happens as a result of different management choices. They do not specify which set of conditions is better or more desirable. In order to make such determinations, an evaluative component is needed. For example, at very low flows rapids on a river may be non-navigable or uninteresting (too easy) for whitewater boaters, and at very high flows they may become dangerous. An evaluative component is needed to decide whether (1) whitewater boating is a desirable goal and (2) what range of flows creates minimally acceptable or optimal conditions. The evaluative component thus includes both management objectives (which indicate the kinds of opportunities managers want to provide) and specific evaluative standards (which specify the conditions necessary to provide those opportunities).

Successful resource management decisions require a degree of consensus about management objectives and evaluative standards. These evaluative criteria usually involve a combination of expert judgment and the opinions of the public, interest groups, and resource users.

The recreation literature review suggests several specific considerations for the Beaver Creek study:

1. Organizing descriptive information about the resource and management goals and objectives is the first step in determining needs for instream flows. The River Management Plan (USDI, 1983) provides a description of the existing physical and biological characteristics,

management goals, and current recreational uses of the area. This information will be referred to here in order to provide background for the instream flow study, but for a thorough description the reader is referred to the Plan.

2. Using information from the River Management Plan, the Wild and Scenic River Study Team Report (USDI, 1973), land managers, river users, previous studies, and field work, the important attributes or characteristics of river use from the recreational and aesthetic points of view are identified. These attributes specify the impact parameters that would be affected by changes in flow regimes. A traditional form of obtaining user preferences and perceptions--the formal user survey--was not possible here. Current recreational use on the river is limited to a handful of trips per year with a total of perhaps 30 people; there are no records of these visitors that would provide a user population to sample from. The advantage of the small number of visitors is that some of them are known to local land managers and have been contacted. Two river parties were also contacted in the course of the 1986 field work.

3. Attributes are considered in terms of their relation to flows, based on information from the sources listed above. Changes in flow regimes are evaluated based on the goals specified in the River Management Plan.

4. Information from the hydrologic study is used to predict how potential or future changes in stream flows might affect recreation or aesthetics.

The resource values that formed the basis for the Wild and Scenic designation on Beaver Creek were presented in the original study report (USDI, 1973) and are listed on page 25 of this report. The River Management Plan for Beaver Creek (USDI, 1983) makes a commitment to obtaining a "reservation of minimum water flows sufficient for public recreation and to support the values for which the area was designated."

Beaver Creek provides opportunities for a variety of recreation activities. All of these rely heavily on the river and its remoteness and primitive character for their high quality. Winter use is by snow machine and aircraft, but is not discussed here because it is not related to stream flows. Non-winter use is primarily centered around float-boating in canoes or small rafts.

The River Management Plan specifies a number of long-term objectives. Among these are "preserve the river and its immediate environment in its natural, primitive condition" and "provide high-quality primitive recreational opportunities for present and future generations."

The Plan then points out that:

- "the existing limited surface access to or across the river corridor in summer has been an important factor in maintaining the primitive setting."

- "primitive areas are characterized by low interaction among users and minimal evidence of other visitors and user controls," and

- "past presence of motor vehicles and surface disturbance caused by vehicle use may have impaired the primitive recreational opportunities expected by the public on a national wild river."

These statements underscore the importance of primitive characteristics of the area for the types of recreation opportunities that are to be provided.

In considering the possibilities for access, facilities, and other developments, the plan also points out that:

- "improved surface access will increase the level of visitor participation and interaction,"

-"an increase in visitor use may occur if improved aircraft access to a take-out point along the river was provided,"

-"the development or authorization of facilities may conflict with the primitive setting as perceived by some of the public," and that

-"as interaction between users, signs of other users, or evidence of on-site management controls increase or become apparent, the primitive recreation opportunities expected by the public on a national wild river may be impaired."

It is thus clear that many critical management considerations hinge upon the primitive nature of the recreation experience. A number of actions that in other settings might be undertaken with little consideration--including even minor improvements to access or facilities--could possibly cause major changes in the "outstandingly remarkable recreational opportunity" that is currently available on Beaver Creek.

Beaver Creek National Wild River starts at the confluence of Bear Creek and Champion Creek (see Figure 1). It is possible to start float trips at this point, but most trips enter the river 6 miles downstream at the confluence with Nome Creek. At this point there is more water for floating (because Nome Creek is a major tributary) and it is also unnecessary to fly in by helicopter (a fairly expensive proposition for the general public), because the Steese Highway and U.S. Creek Road provide overland access to Nome Creek. Boaters using this access must float down the lower part of Nome Creek into Beaver Creek.

A typical trip, then, starts at Nome Creek and takes somewhere between 4 and 10 days to float the 104 miles to Victoria Creek (WRM 110). It is possible to leave the river in this area by aircraft landing on gravel bars or on floats. Some river runners choose to continue downstream past the end of the BLM-managed wild river segment (WRM 127), taking out at the Yukon River-Dalton Highway Bridge, an additional 268 river miles requiring 8-14 days.

At the start of the river trip, Beaver Creek is a relatively small stream that can be crossed easily in hip waders in many places. Floaters need to use care in maneuvering their craft to avoid the banks themselves as well as trees and branches ("sweepers") that extend from the banks. In places where the river becomes shallow or is obstructed by trees or logs, it is often necessary to get out and drag one's boat for stretches of 10 to 50 yards.

At first the river is surrounded by rolling hills, but later it flows past the jagged limestone outcroppings of the White Mountains, which rise 4 to 5,000 feet above the river. Vegetation includes treeless areas of alpine tundra, sparsely vegetated black spruce bogs, and open spruce-hardwood forests. Sometimes dense vegetation grows right along the water, but usually gravel bars provide for a fairly open river corridor.

Although there is no whitewater, Beaver Creek is a relatively fast-flowing meandering stream with fairly constant gradient. It is thus possible to cover a fair number of miles in a day. In addition to floating, boaters may spend time hiking, particularly in the White Mountains area, which offers spectacular scenery and relatively open country and good walking. Fishing is another favorite pastime, with good-sized grayling waiting to be caught on a variety of types of tackle. The open nature of the river corridor offers good opportunities for scenic vistas and viewing the wide variety of wildlife.

Floaters camp along the river. There are a few public use cabins, but most camping is in tents, either in spruce forests or on gravel bars. Gravel bars are generally preferred because they are more open, letting in light, sun, and a breeze to help keep the mosquitoes down to manageable proportions. Gravel bars also provide flat, sandy areas for pitching tents and allow better views of scenery and wildlife. Driftwood for campfires is left by high water. Annual high water also scours gravel bars and leaves them clean and natural-looking (Figure 5).

Figure 5. Gravel bars offer high quality camping opportunities and serve to broaden river viewsheds. Oxbows, when intersected by the river, provide good backwater habitat for Arctic grayling.

A list of float trip attributes was needed to summarize the recreational experience on Beaver Creek. The Grand Canyon instream flow study (Bishop et al. 1987) is particularly helpful here because it involved an investigation of attributes based on surveys of both river users and experienced guides and trip leaders.

Using that information as well as information about Beaver Creek from the River Management Plan, Study Team Report, land managers, river users, and field work, a list of important attributes for recreational trips on Beaver Creek was developed and is presented in Table 3.

Table 3

Attributes of float trips on Beaver Creek

Trip attributes

being in a natural setting
remoteness/primitiveness of the setting
solitude
relaxing, getting away from it all
scenery/views
viewing wildlife
hiking
fishing
canoeing
unobstructed travel
ability to avoid sweepers and snags
reasonable speed of travel
minimal dragging/portaging of boats
flexibility, time for other activities
camping
hunting

Campsite attributes

primitive camping
clean, unlittered sites
natural appearance
scenic view
as few mosquitoes or flies as possible
nearness to river
place to secure boats
flat, open area for tents
solitude/isolation from other groups
good water quality

Aesthetic attributes

scenery
views/vistas
presence of water
sight and sound of flowing water
good water quality

Being in a natural setting is probably the primary attribute of float trips on Beaver Creek. Particularly important here is the remoteness and primitiveness of the setting and the opportunity for solitude and "getting away from it all" which it offers. Although Beaver Creek is not a legally designated wilderness, it seems clear that a back country-type experience is one of the most important aspects of the river trip.

Given this, The River Management Plan points out that it is important to avoid actions that compromise the primitiveness, naturalness, or wild character of the river corridor. The obvious factors here are developments such as roads or buildings that might decrease primitiveness in and of themselves or change the character of the area through dramatic increases in use.

Changes in flows are less obvious management factors that could have equally dramatic effects. At the low-flow end of the spectrum, minimum flows that approximate the current minimums in the natural regime in terms of volume and water quality are probably necessary for the river to appear in its natural state. Such flows are probably also necessary to maintain natural vegetation.

At the high-flow end of the spectrum, the high-water events that occur naturally with breakup in the spring are also important to the natural appearance of the river corridor. These high flows are responsible for the open gravel bars that line the river banks, and eliminating such flows would probably alter the natural character of the river. Observations of successive flood plains along the river show that gravel bars that have not been scoured by recent high flows quickly grow alder thickets that dramatically change the character of the river bank. This change affects a number of other important trip characteristics that are discussed below.

Viewing scenery and wildlife is another important aspect of a river trip. The flora and fauna of the riparian zone obviously depend on some minimum flow. But perhaps more important for these trip attributes is the existence of regular high-flow events. In places where gravel bars have not

been recently cleared by high flows, alder and willow thickets quickly grow to a height of 10-30 feet. When these trees are close to the water's edge, they form "walls" and occasionally partial canopy for the river corridor. This dramatically decreases the scenic vistas and the likelihood of seeing wildlife from the river.

Hiking is also popular on river trips. Walking along the river banks is most pleasant on open gravel bars (it is possible but less pleasant to force one's way through alder thickets). This activity thus depends on high flows that keep gravel bars clear. Hikes away from the river are most commonly done in areas where slopes rise steeply from the river bank, as they do in a number of places where the river flows near the White Mountains. Here the quick gain in elevation allows dramatic views, and the well-drained slopes provide good walking (in contrast to swampy spruce bogs and tundra found in flat areas). Flows have an effect here to the extent that open gravel bars along the river allow access to steeper slopes without having to push through alders.

Fishing is a major attraction, and the grayling fishery in Beaver Creek is one of the area's outstanding attributes. Holmes (1981) found grayling to be the most popular sport fish among anglers fishing in interior Alaska. Some floaters simply catch and release, others keep some portion of their catch, and others depend on fish as a food source during their trip. The fishery is discussed at length in another section of this report, but it is important to point out here that any change in flows that decreased the quality of the fishery would be a serious detriment to the recreational quality of the Wild River.

Canoeing is the primary method of river travel (Figure 6). Although the river is relatively small and has no whitewater, the constant gradient provides for a swift current, and it is possible to travel at a good speed if travel is relatively unobstructed. Because the stream is small and meandering, boaters must be vigilant to avoid being swept into banks, snags, or downed trees which extend from the banks. In areas where the stream channel divides and becomes shallow or is obstructed by trees or logs, boaters sometimes have to get out and drag their boats. Although some of this is an

Figure 6. Beaver Creek offers excellent canoeing. In certain reaches stream velocities are low and paddling becomes common.

unavoidable part of the trip, reasonable boating conditions obviously mean keeping this to a minimum. During field work, which was done at moderate to high (never low) flow, this was necessary approximately six times the first day, five the second, and three the third. It was also necessary twice later in the trip in the vicinity of the White Mountains.

Reasonably unobstructed canoe travel is heavily dependent on flows. Minimum flows which approximate current lows in the natural regime are necessary to provide enough water to keep from running aground too often and to allow enough room to maneuver around sweepers, snags, and log jams. Less water would clearly mean an increase in both the number and length of portages, and could possibly turn Beaver Creek into a series of tiny flatwater ponds connected by long portages over gravel riffles too shallow to float. Lower flows would also cause a decrease in current speed, restricting the

mobility of floaters and decreasing the time available for other activities. High flows which approximate current spring floods are necessary to remove sweepers, snags, and log jams from the river channel. They also keep the gravel bars clear so that when portaging is necessary it can be done with reasonable efficiency.

Camping is an integral aspect of float trips. As the River Management Plan and numerous other sources suggest, primitiveness is a crucial element. This means clean, unlittered sites and a natural appearance. As with traveling on the river, scenic views are important. Although it is probably not possible to float Beaver Creek without encountering some mosquitoes, there clearly are areas which have fewer annoying insects, and this is an important feature of a camp. Camping near the river is both a pragmatic (because there is less distance to carry gear) and an aesthetic attribute of a camp site. A place to secure boats and a flat open area for tents are also important (Figure 7).

Figure 7. Open camping is available on gravel bars. Gravel bars are high flow-dependent channel morphological features.

Flows affect these campsite attributes and high flows are particularly important. Periodic spring floods scour the gravel bars and keep them clean, unlittered, and natural-appearing. This cleansing effect of a natural flow regime has become particularly apparent by its absence in other rivers where dams have restricted flows and allowed the effects of human use to build up year after year. High flows also keep the gravel bars open, allowing a scenic view as well as the sunlight and breeze which help keep the mosquitoes down. Venturing even 10-20 yards off the gravel bars into the alders produces an almost instantaneous swarm of insects. The gravel bars also offer the only reasonable opportunity to camp in close proximity to the water, as well as well-drained flat areas for tents. In older floodplain areas where there have not been recent high flows to keep alders cleared out it is often impossible to find a clear area large enough to pitch a tent.

Solitude is another attribute of camps which is preferred by back country travelers. Although not directly related to flows, solitary camps are more likely when current speed and unobstructed travel allow floaters the flexibility to travel farther to avoid camping near other parties. It appears that the number of floaters on Beaver Creek is so low that this is not an issue at this time, but it could become a problem if use increases.

The effects of flows on aesthetic attributes have been mentioned tangentially in the preceding discussion. Scenery and views would change if low flows below the current minimums altered the character of streamside vegetation or if high-flow events were not present to keep gravel bars clear and provide an open river corridor. The presence of water is an obvious attraction of a river trip, particularly moving water. Current minimum flows leave Beaver Creek low enough to drive across in a small-wheeled all-terrain vehicle (Miller, 1986). Low flows below that minimum could leave a virtually dry streambed with stagnant pools, a situation with considerably less aesthetic appeal than a flowing stream.

Fishery Habitat

The BOR study report on Beaver Creek (USDI, 1973) listed "outstanding grayling fishery" as one of the wild river attributes. Since fishery habitat

is strongly dependent on water levels, field observations from Beaver Creek were used in conjunction with results from a literature review to determine relationships between grayling habitat criteria and flow levels.

The arctic grayling (Thymallus arcticus) is a holarctic species that extends in North America across northern Manitoba, Saskatchewan, Alberta, British Columbia, the Northwest Territories (Hubert et al., 1985), the Yukon, and most of Alaska (Krueger, 1981).

In Alaska grayling begin to move upstream under the river ice of the large streams in early spring. Upstream migration by mature adults begins when the water temperature is 32° to $39^{o}F$ (0° to $4^{o}C$) and the streams become passable. When the ice melts, adult grayling move into small spawning streams. In Beaver Creek, spawning occurs between mid to late May and late June (Webb, 1986). Adults return to the larger rivers after spawning, while juveniles remain in the spawning streams most or all of the growing season. By late summer or fall, all fish have moved downstream to wintering areas (Hubert et al., 1985).

Arctic grayling may migrate long distances to reach tributary spawning streams. Arctic grayling may migrate from 6 to over 90 miles (10 to 150 km) to find suitable spawning areas (Hubert et al., 1985).

Arctic grayling spawn annually once they reach sexual maturity (age undetermined). At least some fish are believed to home to individual streams to spawn (Warner, 1955; Craig and Poulin, 1975; Tack, 1980). Males initiate spawning activity by establishing spawning territories. Territories are 10 to 100 ft^2 (1 to 10 m^2). Spawning has been observed to occur at 36 to $50^{o}F$ (2 to $10^{o}C$), with most activity in the upper end of the range (Hubert et al., 1985). Spawning lasts 2 to 24 days. Spawning usually occurs over ground substrate with transition areas between the lower end of a riffle and a pool favored. Current velocities at spawning sites range from 1.12 to 4.79 f/s (0.34 to 1.46 m/s). Grayling have been observed to spawn over mud-bottomed pools with vegetation, above rapids, and in shallow backwaters with no specific substrate selection. In Beaver Creek, spawning has been observed over light sandy and silty substrates in low flow areas of the larger tributaries and in side sloughs (Webb, 1986).

No redd is prepared by either male or female grayling, although small depressions may result from tail vibrations. During the spawning act, sand and small gravel coats the adhesive eggs while settling to the stream bottom (Hubert et al., 1985). The characteristic large dorsal fin of the grayling is of major importance during the spawning act. (Krott and Smith, 1980).

Eggs hatch in 8 to 27 days at water temperatures of 36 to 61°F (2.0 to 16.1°C) (Henshall, 1907). Fertilized eggs require only 8 days to hatch in 60°F (15.5°C) water at an Alaskan hatchery (Kreuger, 1981). Eggs are most abundant in rubble and gravel substrate, generally in the transition between a riffle and pool (Nelson, 1954). Many eggs commonly drift downstream soon after being spawned (Warner, 1955). Mortality during the embryo stage is high; Kruse (1959) estimated mortality to be 96% during embryo development.

Fry emerge from the gravel and remain in the small spawning streams throughout the summer (Craig and Poulin, 1975). In Beaver Creek fry have been observed to move into side sloughs where low-velocity water and cover are available (Webb, 1986). Fry are known to use interstitial spaces, shadows, and boulders (Krueger, 1981) and large woody debris (Webb, 1986) for cover. Quiet water areas such as backwaters, side channels, and sloughs are principal habitat for young grayling until late summer when they become more territorial and move into deeper water (Armstrong, 1982).

They reach 1.8" to 2.8" (45 to 70 mm) total length their first summer in Alaskan waters (Craig and Poulin, 1975; Netsch, 1975), and grow approximately 1.6" (40 mm) per year through age VI.

The life span of Alaskan grayling is believed to be 15 to 22 years (de Bruyn and McCart, 1974; Armstrong, 1982). The largest grayling recorded in Alaska was 21.5 inches (546 mm) and 4.7 lbs. (2.13 kg).

Optimal Arctic grayling riverine habitat is characterized by cold water and abundant pools. Grayling are found almost exclusively in pools, seldom in riffles (Vascotto and Morrow, 1973). Bishop (1971) reports use of riffles as feeding areas.

Adult fish spend most of their time in a current of about 0.85 f/s (0.26 m/s) (Krueger, 1981). Vincent (1962) defined Arctic grayling habitat as water with a velocity between 1.02 and 2.00 f/s (0.31 and 0.61 m/s); gradient 0.09-0.28% with a maximum of 0.38% (Liknes, 1981) found grayling to be most abundant at 0.69 f/s (0.21 m/s), gradient - 0.29%. Adult grayling are tolerant of water temperatures in excess of 68°F (20°C) (LaPerriere and Carlson, 1973).

Webb (1986) has observed that large, mature adult grayling in Beaver Creek are mostly found between the Big Bend area and the Beaver Creek-Nome Creek confluence.

Adult grayling consistently avoid turbid waters below placer mines, but they can survive under turbid conditions (Reynolds, 1984). Grayling tend to associate with aquatic vegetation in both lakes (Erickson, 1975) and streams (Liknes, 1981). In streams, such habitat is associated with pools and fine-sediment substrates (Vincent, 1962; Liknes, 1981). Grayling are not strong swimmers and therefore require resting cover (Webb, 1986).

Arctic grayling are sight feeders. They begin to take feed four days after hatching (Brown and Buck, 1939). Young-of-the-year, stream-dwelling fish consume primarily small immature aquatic insects, including diptera larvae and pupae, mayfly larvae, and caddis fly larvae (Hubert et al., 1985). As juveniles and adults they depend heavily on benthic and terrestrial insects in the stream drift but they have been observed to feed opportunistically on fish eggs, small fish, and mammals (Reed, 1964; Vascotto and Morrow, 1973; Elliott, 1980).

Webb (1986) believes that grayling populations in Beaver Creek depend largely on and adjust to the availability of winter water supply and food.

Beaver Creek is basically moderately swift and generally has shallow pools with some being deeper than ten feet during the open water season. Substrate consisted of a variety of materials depending on the location of the stream, but usually consist of small gravels and cobbles. Cross-section samples

indicate that there is no difference in size of substrate materials. The average diameter for larger materials was 90 mm; medium size substrate averaged 59 mm, and smaller gravels averaged 28 mm (see Appendix B).

Aquatic habitat is generally in pristine condition with the exception of the Nome Creek tributary where placer mining for gold continues. Both permanent and temporary habitats are used by fish, especially grayling. This depends upon the water levels and flows in Beaver Creek. Rising levels and increased flows cause inundation of backwater areas, side channels, oxbows, and depressions along the shoreline. Grayling seek refuge in these habitats to rest, feed, and escape predation and fast flows. Some fish may become trapped in these backwaters and oxbows when water levels drop. Mortality may occur if the fish do not leave and these backwater areas do not contain sufficient depth to sustain fish over winter.

During the July survey, observations indicated that pools were limited throughout Beaver Creek. Available pools were primarily located near log jams, undercut banks, steep cliffs, and stream bends. Water levels were approximately 2 feet below bankfull level prior to the rain. Flows ranged from 134 cfs at WRM 0 to 4525 cfs at WRM 109.5 during the survey of the mainstem (Appendix B).

Habitat requirements for grayling in Beaver Creek for spawning, rearing, migration routes, and overwintering areas needs further verification and documentation. Three stream cross sections (WRM-12, WRM-33, WRM-39) surveyed appeared to contain spawning substrate of fine gravels and sand scattered throughout these stations. For the remainder of the survey (7/30 to 8/1), water levels and turbidity were high so the positive identification of spawning areas could not be made. It was too late in the year to observe spawning grayling in the mainstem. Spawning areas consisting of sand and small gravel are preferred as these materials coat the adhesive eggs while settling to the stream bottom (Kruse, 1959). The previous fishery studies (Webb, 1982-86) found spawning habitats to be scattered throughout Beaver Creek. We do not have data on precisely when or where grayling spawning occurs in Beaver Creek. Apparently spawning occurs downstream in late May. In upper Beaver Creek and isolated areas it may take place in the middle or latter part of June.

Some rearing areas were delineated before the high water levels made observations unreliable. Two sites were observed (WRM-33, 39). Grayling fry and fingerlings (1 to 3 in.) were observed in shallow backwaters and depressions along the mainstem. Approximately 30 fingerlings were observed at WRM 33 and about 55 at WRM 39. Location of large springs above WRM 39 may serve as a rearing site. The role of sloughs in grayling life cycle has not been studied in detail. Observations during the survey indicated that fry, fingerlings, and adults use sloughs temporarily for rearing and feeding.

Migration routes are not precisely known but it is believed that the mainstem serves grayling in movements up and down Beaver Creek. The stream splits off at several locations and rejoins at several sites downstream. Because of this diversion the mainstem appears to be the primary route based on depths and flow regimen.

Overwintering areas possibly exist throughout the Beaver Creek watershed, but are in very short supply in extreme upper Beaver Creek. One site has been delineated about a mile above WRM 39 (Webb, 1986). It is here that several large springs keep a two-mile or so river section open during the winter. Other overwintering areas for Beaver Creek have been delineated by Webb (1982-86) on 1:250,000-scale maps.

In our judgment the main channel pools provide crucial overwintering habitat in Beaver Creek. Also, pools serve as feeding, escape cover sites, and resting areas during migrations. Winter water availability for fish overwintering is in low supply due to low base streamflow in the upper Beaver Creek (Webb, 1982). Any loss of pool depth would adversely impact the overwintering survival of the total population of Beaver Creek fish. The few deep water pools provide the prime refuge for adult fish in upstream areas. Fish movements between pools is essentially impossible for adult fish in low flow areas. Based on winter field observations (Webb, 1982), potential refuge areas (deep pools) for adult fish during late winter would have to be at least 8 feet deeper than the upstream riffle to maintain a 4-foot water depth below the ice. Therefore, there is no reduction to be tolerated in the winter low flow.

Based on the July survey it appears that most of the channel areas are used for cover and resting. This is especially so where there are eroding banks that have trees anchored to the shore and where sweepers are present. Grayling forage along the edges of fast water, deep pools, sloughs, and off the edges of riffles that drop into deep pools. Also, they forage in side channels or intermittent streams created by high waters. It appears that grayling utilize 75-80% of the main channel and sloughs as forage areas. Grayling are sight feeders and depend on macroscopic organisms in the stream drift (Reed, 1964; Vascotto and Morrow, 1973; Elliott, 1980). Based on our observations and professional judgment, we believe the main channel plays a major role in providing migration routes, spawning areas, rearing habitat, resting and escape cover where trees are anchored and have fallen into the stream, and overwintering areas. A rapid loss of wetted perimeter would reduce the above access and habitat to juvenile and adult grayling. Because data are lacking on population densities for grayling, the loss of wetted perimeter that would be acceptable is not conclusively known. Any loss will have an adverse impact on the grayling population.

Grayling abundance throughout the stream was attested by survey hook and line sampling and observation of rising fish in the clear stream and backwater areas (Figure 8). Heavy rain and murky waters restricted any further observations of rising fish below Dead Moose Rock.

Figure 8. Arctic grayling fishing is excellent, particularly in main channel pools, at the mouths of tributaries, and in sloughs and backwaters.

Sixty-six grayling taken by hook and line were measured in total length. These lengths ranged from 7 to 14 inches (average=11.7 in). Examination of grayling reproductive tracts indicated that 70% were males and 30% females. Those fish over 12.0 inches were sexually mature based on scale sample analysis (by other investigations) and internal examinations.

New egg development was appearing to take place in most of the females inspected while males showed little or no gonadal development at the time of the survey. This development was noted for all fish over 12.0 inches in total length.

Stomach samples were taken from fish captured to ascertain if aquatic or terrestrial macroscopic invertebrates provided the basic diet (Figure 9). Sixty-six stomachs were examined for food utilization by grayling. The following organisms and percentage of contents were recorded:

Aquatic		Terrestrial	
Aquatic beetles	10%	Ants	2%
Algae	10%	Bees	2%
Caddis fly	12%	Beetles	3%
Chironomids	3%	Flies	5%
Dipteria	12%	Mosquito larva	13%
Grayling fingerlings	3%		
Mayflies	12%		
Nematods	2%		
Plant matter	8%		
Snails	3%		
TOTALS	75%		25%

Samples were not saved or identified to Genera in this survey. Macroscopic organisms such as caddis flies, mayflies, and stone flies can be used as criteria for water quality. Also fish species could be used as indicators of water quality in Beaver Creek. During the survey the water quality met acceptable standards for aquatic life, though some parameters (DO, CO_2) were not sampled.

Figure 9. All sampled fish were measured, weighed, and analyzed for stomach content.

Other species of fish are known to occur in Beaver Creek along with Arctic grayling (Thymallus arcticus). These other species are: Northern pike (Esox lucius). sheefish (Stenodus leucichthys), slimy sculpin (Cottus cognatus), round whitefish (Prosopium cylindraceum), longnose sucker (Catostomus catostomus), king salmon (Oncorhynchus tshawytscha), and chum salmon (Oncorhynchus keta). Upper Beaver Creek is not a salmon spawning stream of any consequence (Webb, 1982).

Observations were made to record wildlife present during the survey. Birds were the most abundant wildlife noted along the stream corridor. Spotted sandpiper, jays, flycatchers, waxwings, finches, kingfishers, mergansers, gadwall, buffle head, bald and golden eagles, peregrine falcon, redtail hawks, two unidentified raptors, and signs of geese were noted along the water's edge on mud flats. A cow moose and calf were sighted below Fossil

Creek. Bear, beaver, and moose signs were observed throughout the survey. A white wolf was observed feeding on a moose carcass near WRM 3.

Water Quality

As of this writing, the potential critical problem confronting Beaver Creek is not water quantity, but water quality. Unfortunately, even if the entire yield of Beaver Creek was determined to be the amount needed for a reserved water right, the natural flows could not overcome the aquatic havoc that would be raised as a result of poor land-use management decisions. (See Table 12 for additional information on Beaver Creek water quality.)

Alaska has an interesting water quality case involving siltation. In G and A Contractors, Inc. v. Alaska Greenhouses Inc. 517 P2d 1379, 1383, 1384, 1385, (1974) the Alaska Supreme Court recognized damages to unique downstream property values as the result of the changes in a stream channel by the defendant. This recognition of siltation damages relies on a fact pattern very similar to the situation which could arise on Beaver Creek as the result of improper mining techniques.

Clearly, the BLM has responsibility to maintain the high water quality values in Beaver Creek. The Wild and Scenic Rivers Act states:

> Sec. 12(c): The head of any agency administering a component of the national wild and scenic rivers system shall cooperate with the Secretary of the Interior and with the appropriate State water pollution control agencies for the purpose of eliminating or diminishing the pollution of waters of the river.

HYDROLOGY AND CHANNEL MORPHOLOGY

The objectives of the Beaver Creek hydrology and channel morphology studies were to:

1. Synthesize mean annual hydrograph, flow duration, low-flow, and flood-frequency relationships from regionalized data, with verification from channel geometry information.

2. Quantify hydraulic geometry relationships and describe stream zone morphological features, their dynamic attributes (both short-term and long-term), and their probable response to changes in flow or sediment regimes.

3. Develop depth-discharge-velocity relationships for selected stream reaches representative of each stratified stream segment, and for reaches determined to be critical reaches for the maintenance of selected resource values.

The purposes of the Beaver Creek hydrology and channel morphology studies were to develop the hydrology and geomorphology information needed to quantify flow requirements for identified wild river values, and to relate instream flow requirements to current hydrologic conditions.

Hydrology

Beaver Creek is located north of Fairbanks, Alaska, and flows generally north to its confluence with the Yukon River (Figure 1). The drainage basin is approximately 1100 $mi.^2$ at WRM 112. The climate of the Beaver Creek basin is categorized as subpolar continental, with warm summers and severe Arctic winters (USDI, 1974). Mean January temperature is roughly $-20^{o}F$. The region has approximately 100 frost-free days and experiences discontinuous permafrost resulting in poor subsurface drainage in many places. Annual precipitation ranges between 5-20 inches, with most precipitation occurring as summer rains. Snowfall averages between 45-60 inches. Rivers freeze in

October and become ice-free in early to mid-May. Winter flows are very low due to the absence of surface runoff, and are sustained largely by in-channel springs.

The following morphologic and hydrologic description of Beaver Creek was provided in the Beaver Creek River Management Plan (USDI, 1983):

> Beaver Creek originates at the confluence of Bear and Champion Creeks (WRM 0). The first 20-mile river segment is streambed averaging 50 feet in width, with an average river gradient of 8 feet per river mile. Except for occasional shallow riffles, sufficient water levels are present throughout the summer season for boats to float this segment . . .
>
> The second river segment (WRM 20 through 100) is characterized by a widening channel which varies in width from 75 to 150 feet with depths averaging 2 to 4 feet. The average river gradient is 8 feet per river mile. Major drainages entering Beaver Creek along this segment include Trail, Wickersham, and Fossil Creeks. At several locations Beaver Creek separates into two main channels which flow separately for up to a mile. The river bottom is a mixture of small stones, pebbles, and sand. Exposed gravel bars are numerous. Water quality is generally excellent, except occasionally when placer mining activities in the headwaters cause turbidity downstream as far as river mile 30.
>
> The final 27-mile segment of Beaver Creek National Wild River (WRM 100 through 127) is characterized by a gradual reduction in gradient as the river flows into the Yukon Flats National Wildlife Refuge at WRM 111. The river gradient lessens from 8 feet per river mile at the beginning of this segment, to less than 2 feet per river mile. The width of the river channel increases up to 150 feet with average water depths of 2 to 6 feet. The major tributary joining Beaver Creek in this segment is Victoria Creek. Broad gravel bars occur more frequently, and the river bottom, while predominately a mixture of gravels and sands, contains more silt material than the initial 100 river miles .

There are no stream gages on Beaver Creek, so historic discharge data are not available. However, USGS gages located on Birch Creek, Hess Creek, and Boulder Creek--in the same physiographic setting--are believed to provide data representative of flow conditions on Beaver Creek. Birch Creek, at the gage, drains a 2,150-mi^2 watershed adjacent to and east of Beaver Creek. The Birch Creek gage was installed in 1908 and provides a discontinuous discharge record. Mean monthly discharge data for Birch Creek for the period 1908-1912 are summarized in Table 4.

Hess Creek, at the gage, drains 662 square miles. The Hess Creek Watershed is hydrologically similar to Beaver Creek (personal communication, R.L. Burrows, U.S. Geological Survey Subdistrict Chief, Fairbanks, Alaska), but is oriented in the opposite direction. It is adjacent to the Beaver Creek drainage on the west. The Hess Creek gage has an 11-year period of record dating from 1971 to 1982. Mean monthly discharge data for Hess Creek are summarized in Table 4. A Log Pearson III flood-frequency analysis for the Hess Creek data is provided in Table 7a.

Boulder Creek, at the gage, drains 31.3 square miles. Although much smaller in size, Boulder Creek is oriented in the same direction and is hydrologically similar to Beaver Creek (personal communication, R.L. Burrows, U.S. Geological Survey Subdistrict Chief, Fairbanks, Alaska). The Boulder Creek gage has a 20-year period of record extending from 1964-1985. Mean monthly discharge data for Boulder Creek are summarized in Table 4. A Log Pearson III flood-frequency analysis for the Boulder Creek data is provided in Table 7b.

To relate the Birch, Hess, and Boulder Creek data to Beaver Creek, we assumed hydrologic similarity between basins and adjusted flows to represent Beaver Creek on the basis of watershed area. The influence of watershed area on selected flows for the Yukon region is provided in Parks and Madison (1985), and is generally supported by Lamke (1979) (Table 5). Mean monthly flows were adjusted on the basis of the area exponent for mean annual flows in Parks and Madison (1985). Mean monthly flows for Beaver Creek, derived from

Table 4. Mean monthly flows at Birch Creek, Hess Creek and Boulder Creek gages (cfs)

	Mean Monthly Discharge, cfs (Standard Deviation, cfs)											
Gage	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Birch Creek					2050 (871)	3640 (871)	1286 (647)	1090 (431)	1319 (655)	500 (268)		
Hess Creek	.32 (.40)	.27 (.39)	.25 (.40)	40 (101)	1180 (659)	608 (335)	370 (353)	390 (285)	417 (292)	74 (63)	7 (7)	1.3 (.9)
Boulder Creek	.03 (.12)	.03 (.13)	.03 (.13)	1.2 (2.15)	52 (27)	43 (25)	18 (12)	15 (21)	12 (8)	2.4 (1.6)	.3 (.5)	.04 (.13)

Table 5. Regional flow formulas for the Yukon Region, Alaska (Parks and Madison, 1985)

Dependent Variable	Formula	n	r^2	SE (log units)
log Q_2	$-0.20 + 0.91 \log(\text{Area}) + 1.02 \log(\text{Ppt.})$	53	.96	.25
log Q_{10}	$0.73 + 0.82 \log(\text{Area}) + 0.74 \log(\text{Ppt.})$	53	.95	.28
log Q_{25}	$1.13 + 0.78 \log(\text{Area}) + 0.62 \log(\text{Ppt.})$	53	.93	.30
log Q_{50}	$0.39 + 0.76 \log(\text{Area}) + 0.54 \log(\text{Ppt.})$	53	.92	.32
log Q_{100}	$1.64 + 0.73 \log(\text{Area}) + 0.47 \log(\text{Ppt.})$	53	.90	.34
Q Annual	$-2.04 + 1.05 \log(\text{Area}) + 1.39 \log(\text{Ppt.})$	53	.99	.10
$Q_{30,10}$ (low flow)	$-3.91 + 1.16 \log(\text{Area}) + 1.63 \log(\text{Ppt.})$	24	.84	.61

the Birch, Hess, and Boulder Creek data are presented in Table 6. Flood-frequency relationships for Beaver Creek, derived from the Birch, Hess, and Boulder Creek data, are adjusted for area by the exponents provided in Parks and Madison (1985) (Table 7). In addition, generalized flood-frequency relationships for Beaver Creek were derived from formulas derived for the Yukon region in Parks and Madison (1985) (Figure 10). Beaver Creek 30-day 10-year low flows were derived from regional relationships in Parks and Madison (1985) (Table 8).

We believe that the average values for mean monthly flows (Table 6) and the regional values for 30-day 10-year low flows (Table 8) represent the best available data for Beaver Creek. It is important to note, however, that the standard deviations on the mean monthly flows are large, suggesting considerable variability between years in mean monthly flows. Also, the 30-day, 10-year low flow (Table 8) represents a summer low-flow condition. Winter base flows may be considerably lower as indicated by the November to April monthly means in Table 6.

A composite flood-frequency relationship (Figure 10) was developed for Beaver Creek based upon the regional relationships in Parks and Madison (1985) but was adjusted slightly to account for field estimates of bankfull discharge (assumed to represent approximately a 1.5- to 2-year return period flow) and for relationships developed for the Hess Creek and Boulder Creek gages. We believe Figure 10 represents the best available flood frequency relationships for Beaver Creek at this time. The 1.5-year flows from Figure 10 are well supported by field determinations of bankfull flows. The bankfull flow has been found in other studies to approximate a 1.5-year return period flow (Dunne and Leopold, 1978).

Channel Morphology

The amount of sediment and water to be discharged by a river is determined by geologic, climatic, and land-use characteristics of the watershed. Every river develops a combination of gradient, shape, and hydraulic variables which allow it to transport water and sediment loads efficiently, i.e., with a

Table 6. Mean monthly discharge for Beaver Creek as derived from the average monthly flows at Hess Creek and Boulder Creek, corrected for watershed area $(A_1/A_2)^{1.05}$

	Mean Monthly Discharge, cfs											
River Mile	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0	.1	.1	.1	6.6	233	158	77	71	67	13	1.3	.22
35	.44	.42	.42	29	1019	691	346	314	295	55	5.9	1.0
112	.93*	.88*	.88*	60	2106	1428	696	649	609	115	13*	1.9*

*These winter base flow estimates may be low for Beaver Creek due to groundwater inflows from the White Mountains.

Table 7a. Log Pearson III flood-frequency relationship for Beaver Creek as derived from the Hess Creek gage

		(Area-Corrected Discharge to Represent Beaver Creek)		
Return Period	Hess Creek Discharge (cfs)	WRM 0	WRM 35	WRM 112
2	5,200	1,224	4,392	8,254
10	8,360	2,270	7,181	12,678
25	10,200	2,951	8,827	15,157
50	11,686	3,490	10,113	17,190
100	13,274	4,158	11,594	19,230

Table 7b. Log Pearson III flood-frequency relationship for Beaver Creek as derived from the Boulder Creek gage

		Area-Corrected Discharge (to Represent Beaver Creek)		
Return Period	Boulder Creek Discharge (cfs)	WRM 0	WRM 35	WRM 112
2	283	1,079	3,875	7,283
10	737	2,463	7,792	13,756
25	1,107	3,487	10,432	17,913
50	1,464	4,478	13,025	22,058
100	1,903	5,570	15,531	25,760

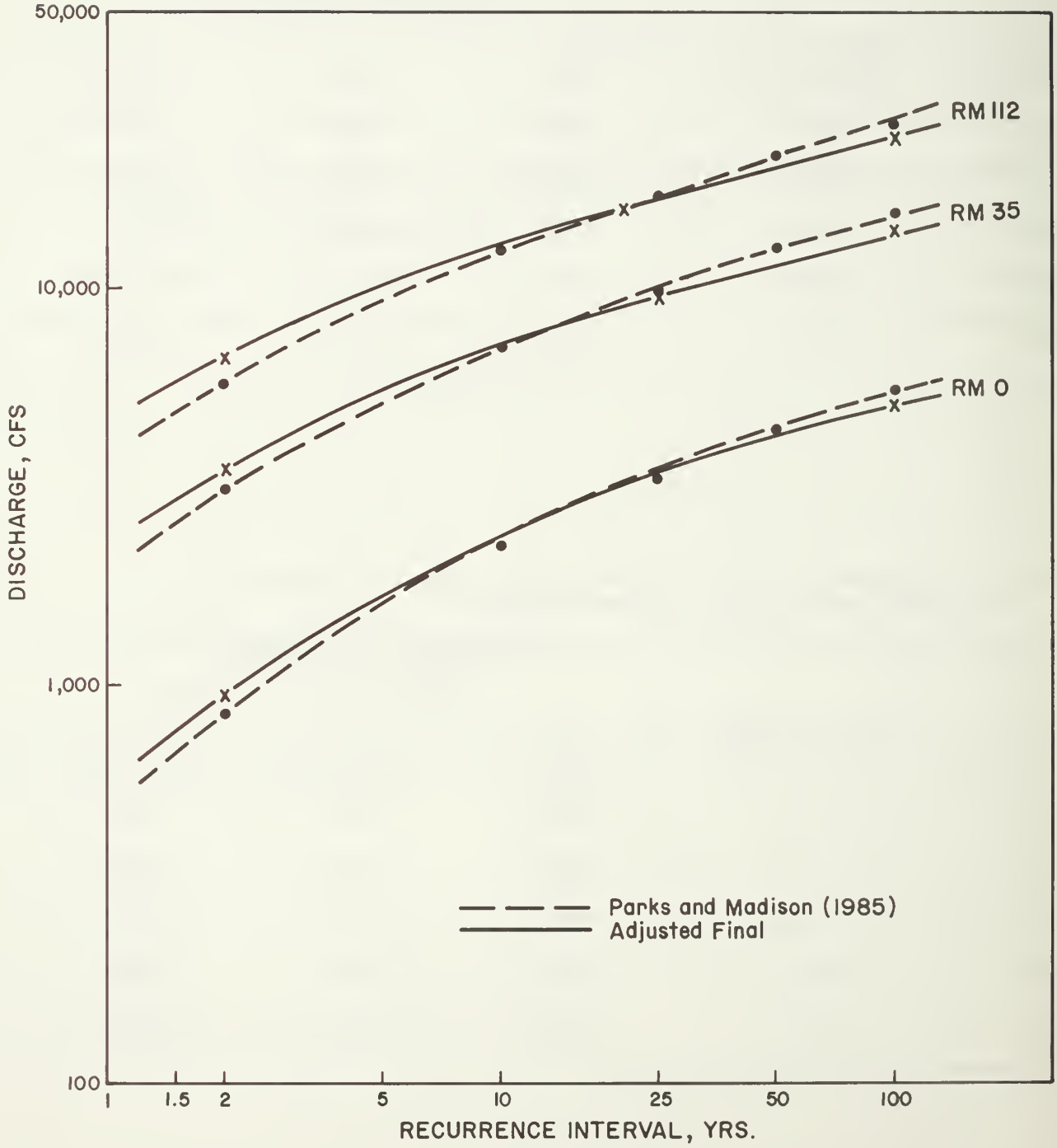

Figure 10. Derived flood-frequency relationship for Beaver Creek.

Table 8. Flood-frequency relationships for Beaver Creek (Parks and Madison, 1985)

	DISCHARGE, Q (cfs)		
Return Period, Years	WRM 0	WRM 35	WRM 112
2	867	3,114	5,851
10	2,224	7,037	12,424
25	3,318	9,923	17,040
50	4,407	12,816	21,704
100	5,596	15,603	25,881
Mean Annual	68	297	614
$Q_{30,10}$ (Low flow)	3.0	15	34

minimum rate of expenditure of potential energy (Ritter, 1978). Thus, all major stream morphological features are interrelated and both control and respond to the expenditure of stream energy.

Channel gradients are usually steepest in the headwaters, and become progressively less steep in the downstream direction. This results in the classic concave longitudinal profile typical of most streams, including Beaver Creek (Figure 11). In the most general sense, stream reaches may be classified based upon their position on the longitudinal profile. Beaver Creek, in the Wild River study reach, was divided into four general slope classes (Figure 12), with each class being subtly, though distinctly, less steep than the preceding class upstream.

Channel shape--or channel pattern--is a plane form channel descriptor. Channel patterns include straight, meandering and braided. When channel sinuosity (the ratio of channel length to down-valley distance) is less than 1.5, a channel is considered straight or sinuous. When sinuosities are greater than 1.5, channels may be classified as meandering (Leopold et al., 1964). Braided channels have multiple channels which continue to divide and rejoin. Meandering and braiding are modes of stream energy dissipation and are related to channel gradient, cross section, discharge, and sediment load. Other factors being equal, braiding appears to be favored by easily eroded channel banks. Meanders are best described by meander length (wave length), amplitude, and mean radius of curvature. Braided, or multiple channels can be described by the number of channels, which in turn may be identified as carrying either major or minor portions of the total flow. Beaver Creek channel patterns are classified in relation to slope class (Figure 12). Beaver Creek is sinuous in Slope Class I, but has both meandering and sinuous reaches in each of Slope Classes II-IV. Meandering seemed most pronounced where valley bottoms were wide. Multiple channels generally occurred upstream from geologic features which would serve to constrict flows during extreme flood events or where meanders were in the process of being "cut off." The largest number of sub-channels occurred in the multiple channel reach immediately upstream from the Big Bend, which--along with the White Mountains--probably served to create a backwater effect during extreme hydrologic events. Beaver Creek has no reaches which exhibit true braiding. It is

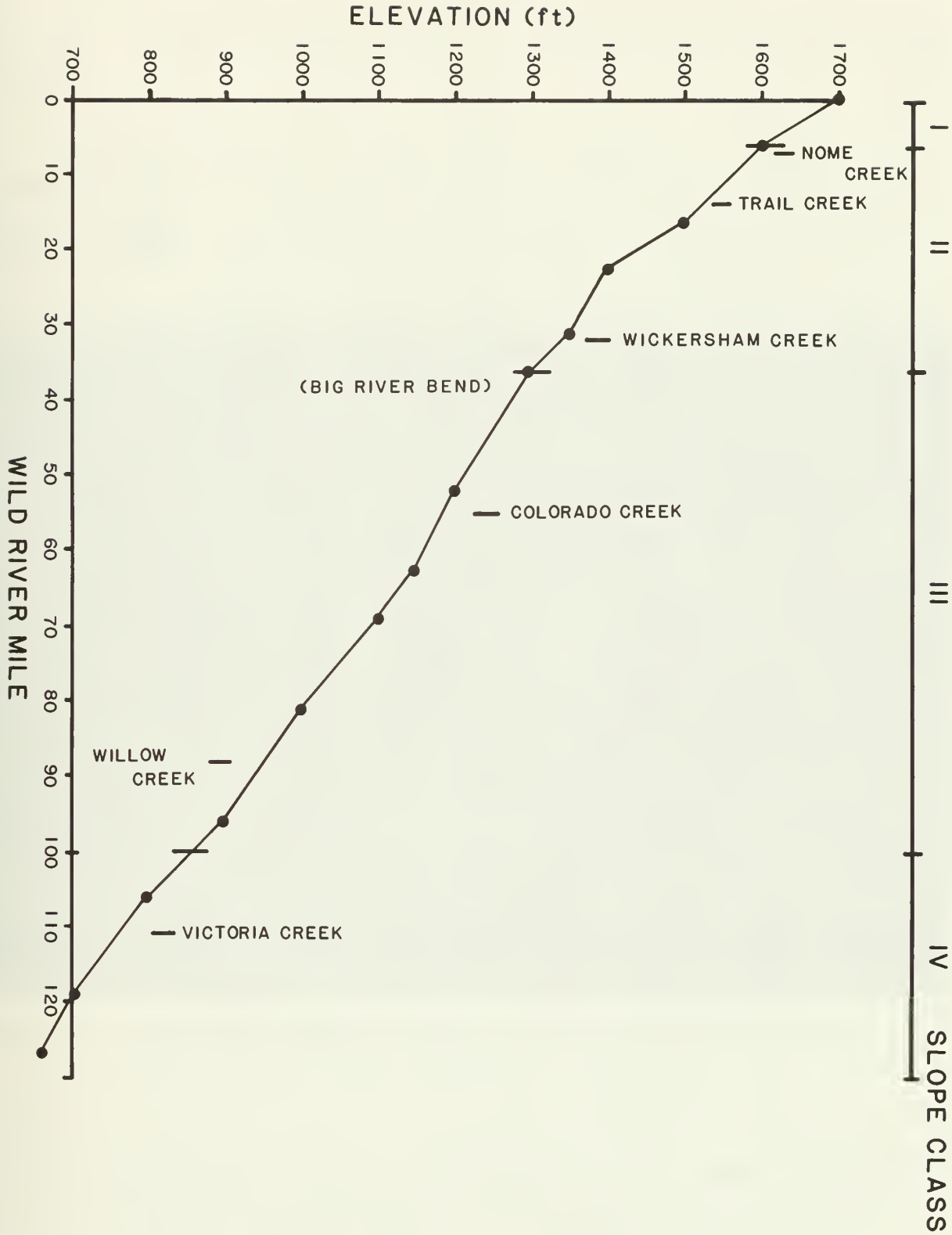

Figure 11. Beaver Creek longitudinal profile.

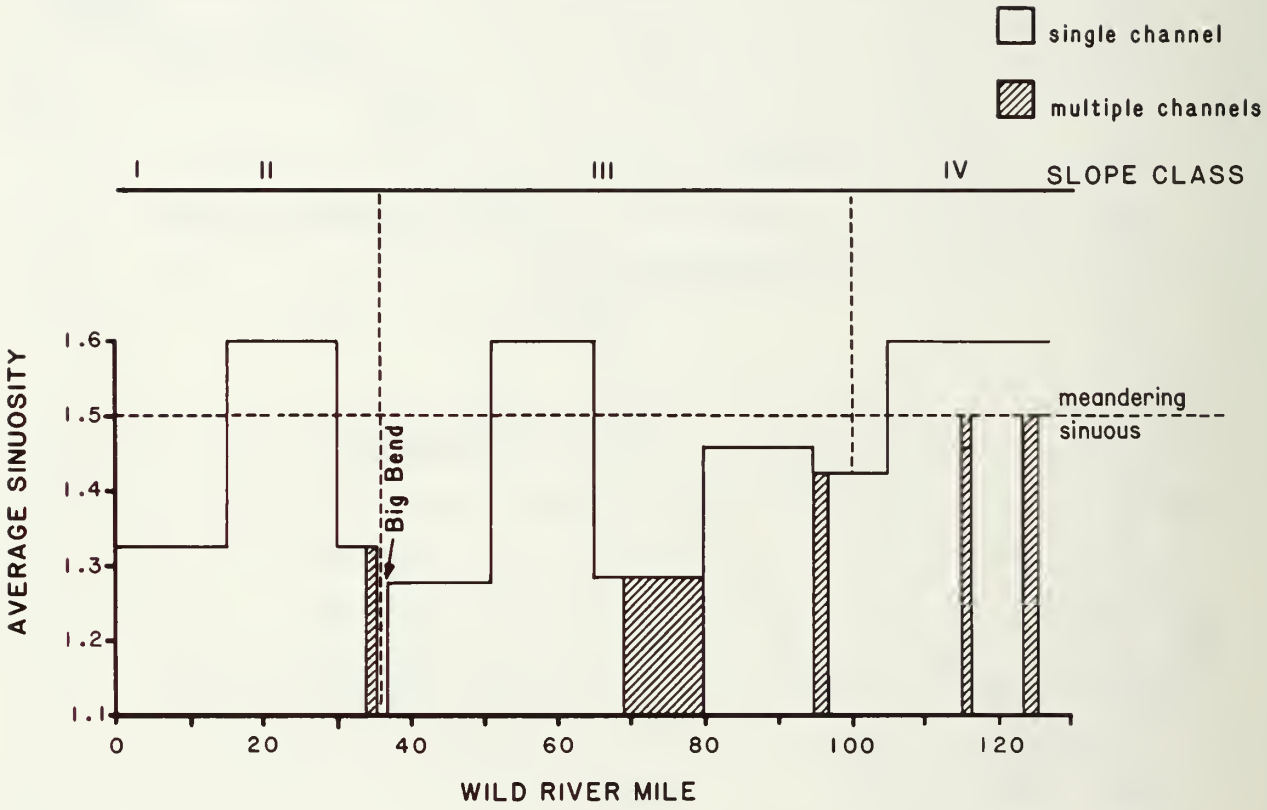

Figure 12. Beaver Creek sinuosity and slope classes.

hypothesized that debris (trees) and ice jams contribute significantly to occurrences of channel realignments and the formation of secondary or multiple channels.

The historic meandering of Beaver Creek has resulted in numerous abandoned channels and oxbow lakes. Some of the most interesting characteristics of Beaver Creek are the numerous sloughs or backwaters created where the present channel intersects old channels and oxbows (Figure 13).

Figure 13. Sloughs and backwater habitat are created where the present channel intersects old channels.

The sloughs vary greatly in size, but generally have low, vegetated banks, fine grained (silts and sands) bottoms and often exhibit beaver activity (Figure 14). Rates of meander growth and the frequency of new meander cut-offs and channel realignments are not known.

Figure 14. Sloughs often exhibit beaver activity.

Certain morphological features contribute to both the natural character and biological quality of streams. These key morphological features include pools, bars, banks, organic debris, rocks, and geologic controls (Beschta and Platts, 1986). Pools are most commonly defined as relatively deep portions of channels. Often they are areas of converging flows or large secondary currents. Primary pools in Beaver Creek are usually found at meander bends and are associated with point bars. They are characteristically deep (4-8 feet) and exhibit a strong helical secondary flow pattern. Secondary pools (3-5 feet deep) are associated with side bars (or alternating lateral bars), mid-channel bars, or backwaters caused by bank irregularities or other flow deflectors. Plunge pools are usually associated with plunging flows over large boulders, logs, or waterfalls or flows into steep bedrock banks.

The deepest pools measured in Beaver Creek (8-12 ft.) occurred infrequently where the river butted against bedrock banks. A region of 7- to 9-ft. pools occurred along the White Mountains between WRM 38 and WRM 48. Several very deep (10-12 ft.) pools occurred near WRM 80-90 where the river butted against shale bedrock banks (Figure 15).

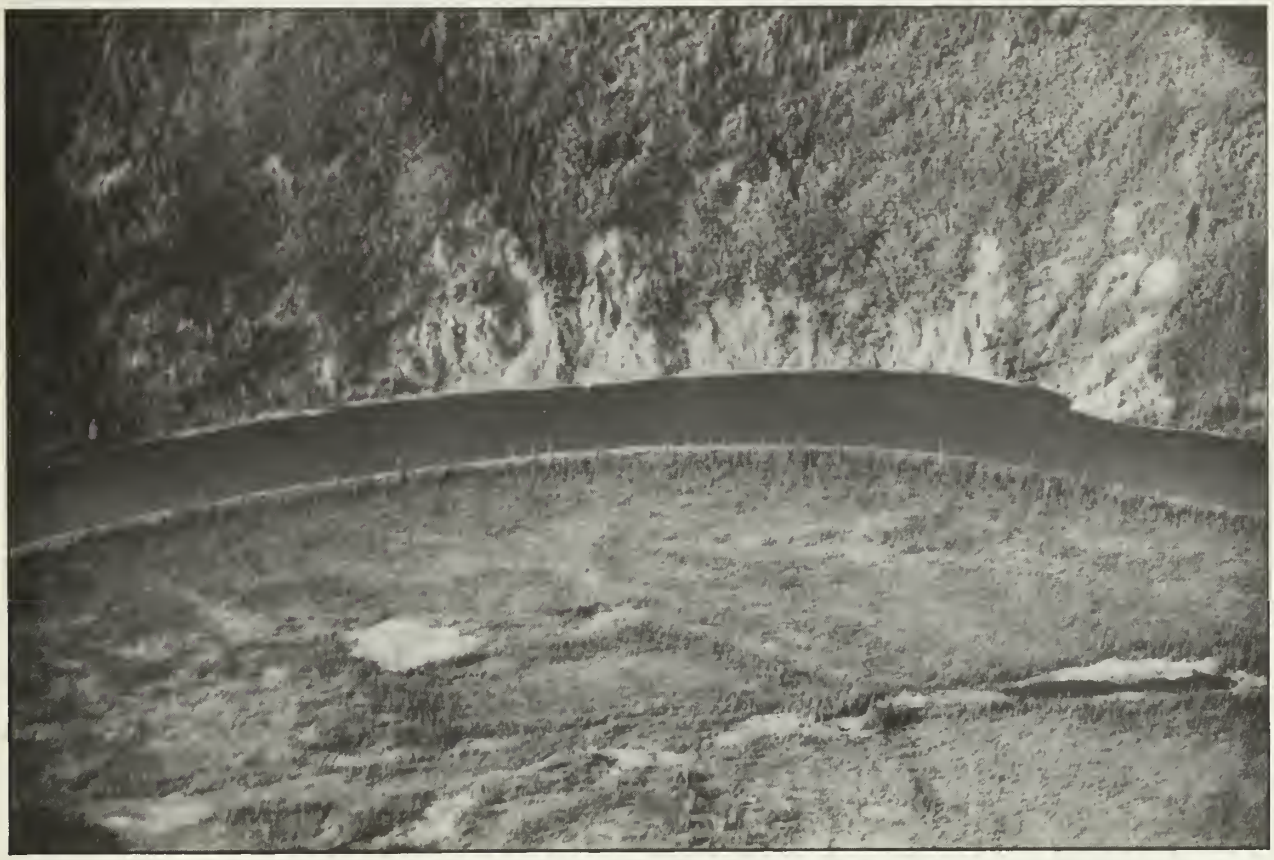

Figure 15. Deep pools exist where the river abuts against bedrock valley walls.

Riffles--or shallows--occur in zones of diverging flow, often where flow paths "cross over" from one channel bank to the other between successive meander bends. Riffles also may be submerged portions of bars. The shallowest flows in Beaver Creek occurred at crossovers and where the stream was just entering a split channel reach. Other shallow reaches occurred where flows diverged due to debris jams. Maximum shallow depths varied from 0.5 to 2.5 feet in depth. While extremely shallow (0.5 ft.) maximum depths occurred

throughout most of the wild river length, they were more pronounced and more frequent in upstream reaches--particularly above the confluence of Nome Creek (Figure 16).

Figure 16. A shallow riffle near WRM 0.

Bars are major stream channel depositional features. Bars may be classified as point bars (the inside of a meander bend), side bars (or alternating bars), mid-channel bars (exposed riffles), transverse bars (or diagonal bars), and tributary bars (bars created by tributary streams). Beaver Creek has numerous large cobble point bars (Figure 17) and infrequent, much smaller side bars. Point bars range in size from 50 feet wide by 200 feet long to 500 feet wide by 1300 feet long. They typically exhibit a characteristic vegetation succession from small willow to large willow, followed by alder, and, finally, black spruce.

Figure 17. Large cobble point bars are numerous on Beaver Creek. High flows rejuvenate these bars.

Channel banks are features which index lateral stability, as well as biological quality. Beaver Creek banks varied greatly in terms of their height, shape, steepness, sediment or soil composition, and the degree to which they are stabilized by roots, vegetation cover, organic debris, or rocks. Where the stream was cutting into mature spruce forest, banks were characteristically steep, fine grained and exhibited a clear thermoerosional niching (Ashton and Bredthaver, 1986). River depths were often deep against these banks, and tree fall was common due to soil creep above the permafrost zone and active thermoerosional niching. At the inside of meanders, banks were usually alluvial (cobble) with very mild slopes. Upper banks were usually finer-grained alluvium resulting from sediment deposition in the invading vegetation (willow) zone. On straight reaches, low alluvial banks comprised the bankfull channel. The flood channel banks were typically steeper forested banks comprised of finer-grained soils, supporting mature spruce forest.

Hydraulic Geometry

Channel hydraulic variables include both hydraulic geometry variables and components of flow resistance--both friction and form roughness. Hydraulic geometry variables include channel top width, mean channel depth, cross-section area, wetted perimeter, hydraulic radius, and slope. Given the hydraulic geometry, water surface slope and flow resistance (or roughness) at a cross section, streamflow rate or velocity may be determined using the Manning Equation. Power relationships describing variations in channel width, mean depth, and mean velocity with discharge may be developed for individual cross sections. In addition, most rivers exhibit a characteristic power relationship between bankfull discharge and cross section width, mean depth, and mean velocity in the downstream direction. Methods for quantifying hydraulic geometry at a cross section are thoroughly described in Leopold and Maddock (1953).

Channel roughness, or resistance to flow in channels, is caused by both skin friction and form roughness. Skin friction refers to flow resistance caused by channel sediment particles or vegetation. Skin friction increases as the size of the channel sediment particles increase. Channel sediments (or vegetation) cause flow resistance by creating flow turbulence at the channel boundary. Form resistance refers to flow resistance caused by either channel pattern (e.g. meanders), or by morphological features which cause irregular hydraulic geometries such as pools, riffles, bars, boulders, or logs. The elements of form resistance serve to dissipate stream energy in the form of large turbulent features such as eddies, secondary currents, or plunge flows. Prestegaard (1983) suggests that form roughness caused by gravel bars may be an important component of total flow resistance, accounting for 50-75 percent of total flow resistance in gravel bed streams with high width/depth ratios and low sinuosities.

For hydraulic calculations, flow resistance is indexed by the Manning roughness coefficient--or Manning's "n." Manning's n incorporates all components of flow resistance--both skin friction and form roughness and may be selected from published tables and guides or derived from one of several

empirical formulas. However, the best way to determine Manning's n is to measure discharge in the field, then solve for n in the Manning equation.

Discharge rating curves may be developed for surveyed channel cross sections using indirect discharge measurement techniques. Indirect discharge measurement techniques refer to methods for determining discharge which do not involve directly measuring flow velocities with a current meter (Benson and Dalrymple, 1967). By far the most commonly used indirect discharge method (when use of precalibrated weirs and flumes is not feasible) is referred to as the slope-area method (Dalrymple and Benson, 1967)--also known as the Manning Equation method (USDI Bureau of Land Management, 1979). This method uses a common hydraulic equation, the Manning Equation, to relate discharge at a cross section to the hydraulic and geometric attributes of the cross section. Simply stated, discharge is proportional to the cross-sectional flow area, A, and the slope of the water surface, S (a parameter representing the gravitational forces during flow); it is inversely proportional to the factors resisting flow (e.g., skin friction and form roughness). The Manning Equation is

$$Q = A \frac{1.49}{n} R^{2/3} S^{1/2} \qquad (1)$$

where Q is discharge (cfs) "n" is the Manning roughness coefficient--a flow resistance coefficient, R is the hydraulic radius (area, A, divided by the wetted perimeter).

Cross-section geometry was surveyed at 10 locations on Beaver Creek (Table 1). Discharge, in addition to cross-section geometry, was measured at seven locations (Table 1). Measured discharge data are summarized in Table 9. Discharge rating curves were developed at all cross sections using the Manning Equation and field-calculated values of Manning's "n." Hydraulic relationships were developed in tabular form at all cross sections in accordance with Leopold and Maddock (Appendix B).

Table 9. Discharge measurements - Beaver Creek

	Discharge - cfs	Average V - fps	Manning's n
Q1	134	1.60	.0505
Q2	364	2.72	.03165
Q3	566	2.32	.04675
Q4	681	2.74	.0384
Q5	1615	2.68	.0435
Q6	1469	3.23	.04085
Q7	4525	3.60	.0379
		Average Manning's n = .041	

The equations used to relate the hydraulic geometry of Beaver Creek to the dominant (here defined as "bankfull") discharge, Q_b, are:

$$W = gQ_b^h$$
$$D = hQ_b^i$$
$$V = jQ_b^k$$
$$WP = lQ^{bn}$$

where W is width, d is depth, v is mean velocity, WP is wetted perimeter and Q is discharge. All other variables are fitted coefficients.

Appendix B provides sketches of all surveyed cross sections, and provides all measured discharges and specific at-station hydraulic geometry relationships. Discharge rating curves are provided for all cross sections in the Appendix. Appendix B also depicts particle size distributions of Beaver Creek bed materials.

Channel geometry at bankfull stage (Figure 18) is summarized in Table 10. Bankfull hydraulic geometry relationships for Beaver Creek are:

$$W = 8.33\ Q_b^{.40} \quad (2)$$
$$D = 0.14Q_b^{.42} \quad (3)$$
$$WP = 7.89\ Q_b^{.41} \quad (4)$$

Figure 18. Bankfull stage is indicated by the arrow.

Table 10. Channel geometry at bankfull stage - Beaver Creek

	Top Width (ft)	Average Depth (ft)	Area (sq. ft)	S	P (ft)	R (ft)	Discharge (cfs)
Q1	129.0	1.6	210.6	.003	130.4	1.6	467
Q2	117.4	2.2	262.2	.0029	121.8	2.2	1106
Q4	137.7	3.0	406.7	.0022	141.9	2.9	1490
Q5	223.5	4.4	975.9	.0016	226.0	4.3	3535
Q6	264.8	3.7	979.8	.0033	265.9	3.7	4885
Q7	257.9	5.4	1384.2	.001	259.8	5.3	5235
G1	153.6	2.9	444.4	.003	156.8	2.8	1767
G2	127.0	2.5	320.0	.0029	130.0	2.5	1139
G3	142.4	3.0	421.0	.0029	144.3	2.9	1678
G4	142.9	7.1	1008.8	.0003	145.5	6.9	2303
G5	241.9	4.2	1005.2	.003	293.9	3.4	4530
G6	229.0	3.6	829.3	.002	230.5	3.6	3156
G7	234.0	4.1	968.2	.0028	235.2	4.1	4769
G8	175.2	2.7	478.6	.003	177.1	2.7	1843
G9	197.2	3.7	733.1	.003	200.9	3.6	3450
G10	286.8	3.3	945.0	.0017	287.3	3.3	3123

In general, the bankfull discharge corresponds to the 1.5-year return period flow determined for Beaver Creek from regional relationships. The exponents on the bankfull hydraulic geometry relationships provide an estimate of the magnitude of change which could be expected in channel hydraulic variables resulting from a change in dominant discharge. For example, a 20 percent decrease in dominant discharge would result in a 9 percent decrease in mean channel depth, based upon Equation 2 above. Complete instream flow analyses are developed elsewhere in this report.

Wetted perimeter is often considered to be an important hydraulic parameter related to instream habitat quality. The inflection point in the wetted perimeter-discharge relationship is considered a critical point for the maintenance of habitat quality (Alaska Department of Natural Resources, 1985). Discharge below that point may indicate decreased food production or fish crowding. In Beaver Creek, the inflection point occurs at roughly the mean August (summer) flow.

Difference in at-station hydraulic geometry largely reflect difference in river character. Cross sections Q1-Q3, Q5-Q7, G1-G3, G5 and G10 were selected to represent average conditions at various river locations. Cross section G7 represents a riffle--or shallow--reach, where river depth may be a critical factor in the maintenance of wild river values. Cross sections G4 and G6 represent deeper pool reaches, where again, maintenance of pool depths may be critical to the maintenance of wild river values. Cross sections Q4, G8, and G9 were selected to represent a split-or multiple channel reach, and cross section Q6S (located across from Q6) represents a slough or backwater. Thus, all cross sections are representative of Beaver Creek, and the differences in at-station hydraulic geometry represent the normal range of variability in channel characteristics.

Channel Process and Response

Stream morphological features function in a dynamic sense--either cyclically or incrementally in response to normal conditions, or radically in response to large perturbations or permanent changes in flow, sediment regime, or channel and floodplain conditions. For example, pools and riffles may undergo episodes of scour and fill during passage of high flows (Keller, 1971; Andrews, 1979; Lisle, 1982; Jackson and Beschta, 1982), but may be obliterated if sediment loads increase or if flows decrease (Megahan et al., 1980; Jackson and Beschta, 1984). Fine sediments may intrude into the voids of riffles under certain flow conditions, but may be removed or flushed under other conditions (Reiser et al., 1985; Beschta and Jackson, 1979; Reid et al., 1985). However, if sediment load increases are very large, riffle gravels may become permanently blanketed by fine sediments. Gravel bars may grow and recede predictability in response to normal flow regimes and may

slowly migrate downstream in response to meander migration or adjustment (Vanoni, 1975). However, gravel bars may become more or less prominant in response to changed sediment and flow regimes. Under extreme conditions, bar classification may change and a stream may change from a single thread to a braided condition or vice-versa. Channel banks may erode incrementally in response to meander migration, but may erode excessively if changes in channel morphology induce excessive latteral instability. Finally, whereas hydraulic conditions (e.g. velocity, depth, Froude number) change constantly with discharge, they may be permanently altered by reductions in flow or changes in channel morphology.

Because morphological features are naturally dynamic, and because permanent morphological changes are the mechanisms by which streams respond to changes in discharge and/or sediment regimes, it is extremely important to describe the dynamic attributes of these features and their probable response to changes in discharge or sediment regimes. Several concepts and descriptive models are available which may aid in a professional assessment of the channel maintenance flow issue.

Lane (1955) presented a qualitative relationship between bed-material load, Qs, water discharge Q, sediment size d_{50}, and channel gradient S:

$$Qs \cdot d_{50} \approx Q.S \qquad (5)$$

That proportionality states that water discharge changes will be compensated for by changes in sediment size and bedload sediment transport.

Schumm (1971) developed a proportional relationship between water discharge and the hydraulic geometry variables width w, depth D, meander wavelength L, and gradient:

$$Q \approx \frac{W, D, L}{S} \qquad (6)$$

Schumm (1971) also developed a proportional relationship between the same hydraulic geometry variables and bed-material load:

$$Qs \approx \frac{W, L, S}{D, P} \qquad (7)$$

where P is channel sinuosity.

Equations 2-4 form a framework within which channels may respond to changes in instream flows. Heede (1976) expands upon these proportionalities by discussing channel adjustments in terms of the energy expending roles of morphological features. He hypothesizes that channel response will occur in a predictable hierarchy--with responses requiring the shortest times and lowest energy inputs occurring first. Thus, he suggests that streams will adjust morphological features in the following order: bed form, bed material size (armor), width, pattern, and longitudinal profile. The direction of adjustment will be in the direction of increased or decreased flow efficiency (i.e. increased or decreased stream power) depending upon the change in equilibrium condition. The magnitude of change is best approximated using the hydraulic geometry information developed above. Other field studies (Lisle, 1982; Lyons and Beschta, 1983; Megahan et al., 1980) also support Heede's description of channel response.

The likely morphological response in Beaver Creek to sustained reductions in flow are summarized in Table 11. A complete instream flow analysis and quantification/qualification of potential responses is provided in the section on Instream Flow Analysis and Recommendation.

Table 11. Possible river morphology adjustments caused by sustained decreases in flow.

Morphological Feature	Adjustment	Comment
width	decrease	Hydraulic geometry relationships
depth	decrease	Hydraulic geometry relationships
meander length	decrease	Eqn. 3
gradient	increase	Eqn. 3
pools	fill	Heede (1976)
bed material size	decrease	Heede (1976)
bars	decrease	stream tries to increase sediment transport efficiency
riffles	increase	" " "
width/depth ratio	increase slightly	hydraulic geometry relationships
bank stability	increase	
velocity	decrease	
flood plain/riparian	later successionary vegetation conditions predominate	less adjustment/ rejuvination
sloughs	decrease	less adjustment/ rejuvination

The information in Table 11 is descriptive. Several authors have attempted to prescribe "channel maintenance flows" and/or "flushing flows" to maintain stream channel physical/morphological attributes (e.g., USDA Forest Service Draft Handbook FSH 2509.17, Chapter 30; Tennant, 1976; O'Brien, 1984). Reiser et al. (1985) provide a comprehensive review of flushing flow requirements on regulated streams. Milhous (1986) summarizes and evaluates five methods for evaluating channel maintenance flows. The methods evaluated are the Tennant Method (Tennant, 1976), Hoppe Method (Hoppe, 1976), Effective Discharge Method (O'Brien, 1984); Montana Yellowstone Method (Montana Fish and Game Commission, 1976), and the U.S. Forest Service Wind River Methodology (Rosgen, 1982).

Milhous (1986) concludes that none of these methods are satisfactory and suggests that physical process approaches to channel maintenance flows must be developed.

For Beaver Creek, principally an alluvial stream, it is assumed that channel characteristics directly reflect hydrologic and sediment transport conditions, and that any changes in "normal" conditions will be reflected in channel adjustments. Thus, there is really no such thing as a "maintenance" flow. The challenge is to predict the direction and magnitude of channel responses to changes in flow, and to define "acceptable" levels of adjustment for maintaining flow-dependent values.

The process which probably dominates all others in terms of its influence on channel stability and channel characteristics is spring river ice breakup and ice transport. Ice is clearly an agent in bank scour, organic debris loading, and channel damming and realignment. The role of ice and thermoerosional niching in river bank erosion is described in Ashton and Bredthaver (1986). However, relationships between ice activity and flows are poorly researched and no way was found to consider the influence of flow on ice-channel processes beyond the normal flow-channel relationships described above.

We hypothesize that Beaver Creek channel attributes are most influenced by large flood flows associated with spring breakup (i.e. flows greater than the 2-year return period flow). This hypothesis is supported by the very low rates of sediment transport observed under near-bankfull summer flow conditions at RM 109.5 (Table 12).

Water Quality Analysis

Grab samples were collected at 12 locations on Beaver Creek and analyzed for specific conductance, pH, total dissolved solids, total suspended solids, total solids, and percent volatile solids (organics) (Table 12). In general, Beaver Creek has good water quality. The rains and high flows resulted in periods of turbidity at lower reaches of the river. The analysis suggests, however, that most of the turbidity was organic material at all but the

Table 12. Beaver Creek water quality data

Sample Identification	Specific Conductance ushos/cm	pH pH Units @ Deg. C.	Total Dis-solved Solids ag/l	Total Sus-pended Solids ag/l	Total Solids ag/l	Volatile Solids %
080586-1 Nome Creek	70	7.1 @ 18	71	2.0	90	62
080586-2 Beaver Creek #1 WRM 0.0	55	7.0 @ 18	47	1.0	84	76
080586-3 Victoria Creek High Flow Aug. 1	120	7.2 @ 17.1	131	162	378	22
080586-4 Beaver Creek WRM 10	62	7.1 @ 18.6	101	19	114	56
080586-5 Beaver Creek WRM 54, 7/30	84	7.3 @ 18.7	93	1.0	94	57
080586-6 Beaver Creek WRM 37.5, 7/29	60	6.9 @ 18.3	80	7.0	74	81
080586-7 Beaver Creek WRM 68.5	85	7.2 @ 18.6	71	9.0	120	65
080586-8 Beaver Creek WRM 8	71	7.1 @ 18.5	53	5.0	80	55
080586-9 Beaver Creek Above Victoria, 8/2	89	7.1 @ 19.3	82	52	254	33
080586-10 Victoria Creek 8/2, at mouth	115	7.2 @ 18.6	97	168	496	25
080586-11 Beaver Cr. & WRM 109.5, High Flow 8/1	103	7.1 @ 17.4	79	46	212	40
080586-12 WRM 68.5, 7/31 Day after rain	85	6.9 @ 17.9	71	21	154	49

highest flows. Samples 3, 9, 10 and 11 were collected at flows only slightly less than bankfull which resulted in somewhat higher sediment concentrations.

Winter Maintenance Flows

No published data were available on mid-winter baseflow conditions on Beaver Creek. However, Webb (1982) noted long reaches of open water below WRM 39, along the flank of the White Mountains. In addition, several prominent groundwater upwellings were observed in this reach. It is hypothesized that the White Mountains, a limestone formation, provide a significant groundwater input to Beaver Creek between WRM miles 39 and 45. Unpublished USGS data suggest that midwinter Beaver Creek flows in 1951 at the confluence of Fossil Creek ranged between 35 and 80 cfs (personal communication, Bob Burrows, USGS-Fairbanks Subdistrict Chief). This would represent a large and significant groundwater contribution from the White Mountains--a contribution which might also be extremely significant during periods of unusually low summer-period flows. These flows are in contrast to the extremely low flows observed during midwinter fishery surveys upstream from the White Mountains (Webb, 1982).

INSTREAM FLOW ANALYSIS AND RECOMMENDATION

In this chapter, discharge rates are related to stream attributes, with the objective of identifying minimum flow levels for maintaining critical wild river values.

The annual Beaver Creek flow regime is stratified into three distinct seasons. Winter base flows, while very small, are key to the over-winter survival of arctic grayling. Summer-fall season (July-October) flows directly influence recreational boating conditions (velocities, depths, widths), and fishery habitat (wetted perimeter, velocities). Spring season (May-June) high flows influence key morphologic features such as active channel width, gravel bar size, pool depth, sediment size, and the frequency and size of sloughs and oxbows. Morphological features, in turn, contribute to fishery habitat, camping quality, visual qualities, and boating conditions.

To the extent possible, the effects of alternative discharge rates on primary stream attributes--velocities, depths, widths, slough occurrence, sediment sizes, and wetted perimeters--are quantified. Next, the effects of changes in stream attributes on primary Wild River values (fishery, wilderness recreation, and aesthetics) are described. Finally, a minimum flow regime is recommended to maintain Beaver Creek wild river values (Figure 4). Recommendations are developed for the winter base-flow season, the spring high-flow season, and the summer-fall season. The recommendations are evaluated in terms of any effects on mean monthly water yields in the basin.

Velocities

Average stream velocities decrease with decreasing discharge. Stream velocity is a variable in sediment transport (primarily a high-flow phenomenon), boating speed/float-trip time, the interchange of surface and intergravel flows, and stream temperature. Average stream velocities are calculated at any channel cross section by dividing the discharge rate by the cross-section area of flow. Average stream velocity at each of cross sections Q1-Q7 is provided in Table 13 at the time of stream gaging. Also,

Table 13 provides estimates of average stream velocities corresponding to the mean August flow, 0.9 times the mean August flow, and 0.8 times the mean August flow.

Table 13. Beaver Creek velocity analysis

	Velocities, f/s (avg.)			
X-Sec.	When Gaged	Est. Mean Aug. flow	Est. 0.9 Mean Aug. flow	Est. 0.8 Mean Aug. flow
Q1	1.60	1.2	1.08	0.96
Q2	1.72	1.8	1.62	1.44
Q3	2.32	1.6	1.44	1.28
Q4	2.74			
Q5	2.68	1.8	1.62	1.44
Q6	3.23			
Q7	3.60	1.4	1.26	1.12

The effects of alternative August flow levels on float trip times is evaluated in Table 14. In general, a 112-mile canoe trip would take 8.9 days under conditions of mean August flow. A group could fly out on the afternoon of their 9th day and still fit a trip into a one-week vacation with a weekend on both ends.

Table 14. Effects of flow levels on average flow trip times

	When Gaged	Mean Aug. flow	0.9 Mean Aug. flow	0.8 Mean Aug. flow
Velocity f/s	2.7	1.6	1.4	1.3
Averages: mph	1.8	1.09	.95	.87
112-mile trip time (hours)	62 hrs	103 hrs	118 hrs	129 hrs
112-mile trip time (days) assume 6-hr. days	10.4 days	17.1 days	19.6 days	21.5 days
112-mile trip time (days) adding paddling at 1 mi/hr	6.6 days	8.9 days	9.6 days	10 days

The trip would take 9.6 days and 10 days respectively under 10% and 20% reductions in mean August flow. While the increases in travel time due to flow reductions are not dramatic, they do influence the vacation time required to float Beaver Creek. With the 10% reduction, a tenth day (an extra day of vacation) is required to finish paddling and fly out. The 20% reduction increases the travel time to 10 full days, so now the flight out would probably have to be on day 11. That is already over the limit for the 9-day vacation, but this still means investing the time and money necessary to spend an extra day.

The project did not develop data on the effects of velocity reductions on intergravel flows or stream temperatures. However, it was our judgment that those effects would be less significant than the effects on float trip times, and that comparable 10% or 20% mean flow reductions would not result in significant effects on wild river values. The effects of reduced velocities on sediment transport-related attributes are considered as part of other evaluations in this chapter.

Riffle Depths

Maximum riffle depth decreases directly with decreasing discharge and indirectly as a result of adjustments in channel morphology. Maximum riffle depth is of primary concern to river navigability in Beaver Creek. Even under natural flow conditions, shallow riffle depths (depths less than 6 inches) will sometimes result in the need to get out and drag a canoe several yards to deeper water (Figure 19). This problem is more pronounced upstream from WRM 6 (above Nome Creek) but occurs throughout the wild river reach.

Figure 19. In its upper reaches, Beaver Creek is narrow and shallow. Areas of shallow riffles or fallen trees occasionally must be portaged.

Riffles in Beaver Creek are located at points of diverging flow including cross-overs between meanders, flow splits around bars or islands, and flow separations around large debris (trees). Based upon an analysis of the photos, primary riffles occurred at the rate of 4-5 riffles per mile above the confluence with Nome Creek, and about two riffles per mile below Nome Creek. Maximum riffle depths were sounded randomly along the entire wild river reach using a sounding rod. Measured depths were then reduced to represent depths under mean August flow conditions (i.e. boating season mean monthly flows).

Average maximum riffle depths are provided in Table 15 for WRM 0-6, and in Table 16 for the river below Nome Creek. Since the depth soundings were approximately normally distributed, the percent of all primary riffles less than 6 inches deep could be determined from student T-tables. Tables 15 and 16 also show the percent of riffles less than 6 inches deep for assumed 10%, 20%, and 30% reductions in mean riffle depth, which could be caused by either reduced August flows or changes in channel morphology.

Depth reductions due to reduced August flows were evaluated from the discharge rating curves in Appendix B. Depth reductions due to changes in channel geometry were evaluated using the derived channel geometry relationship for depth.

Based upon the above riffle depth and frequency analyses, it is estimated that a 6-mile trip above the Nome Creek confluence would result in crossing 24-30 good riffles, with about 4-5 incidents of boat grounding under mean August flow conditions. A 10-mile day below the Nome Creek confluence would result in crossing roughly 20 primary riffles, with possibly two incidents of boat grounding under mean August flow conditions. The percent increase in boat groundings due to reduced mean depths is shown in Tables 15 and 16 as the percent increase in maximum riffle depth less than 6 inches.

For the area above Nome Creek, our judgment is that increasing boat drags by approximately one in five (the 19% increase in the 10% flow reduction scenario) would be tolerable to (although probably not preferred

Table 15. Beaver Creek riffle depth analysis above Nome Creek

Flow Level	Avg. Maximum Riffle Depth	Percent Less Than 6 Inches
Mean August Flows	1 ft.	16%
10% reduction in depth caused by either 10% reduction in Mean August Flow or 20% reduction in flood peak flows	0.9 ft.	19% (=19% increase in portages)
20% reduction in depth caused by either 20% reduction in Mean August Flow or 20% reduction in flood peak flows plus 10% reduction in Mean August Flow or by 40% reduction in flood peaks	0.8 ft.	23% (=44% increase in portages)
30% reduction in depth caused by 20% reduction in flood peaks plus 20% reduction in Mean August Flow or by 40% reduction in flood peaks plus 10% reduction in Mean August Flow	0.7 ft.	28% (=75% increase in portages)

Table 16. Beaver Creek riffle depth analysis below Nome Creek

Flow Level	Avg. Maximum Riffle Depth	Percent Less Than 6 Inches
Mean August Flows	1.5 ft.	9%
10% reduction in depth caused by either 10% reduction in Mean August Flow or 20% reduction in flood peak flows	1.35 ft.	11% (22% increase in portages)
20% reduction in depth caused by either 20% reduction in Mean August Flow or 20% reduction in flood peak flows plus 10% reduction in Mean August Flow or by 40% reduction in flood peaks	1.20 ft.	12% (33% increase in portages)
30% reduction in depth caused by 20% reduction in flood peaks plus 20% reduction in Mean August Flow or by 40% reduction in flood peaks plus 10% reduction in Mean August Flow	1.05 ft.	15% (67% increase in portages)

by) recreationists. On an average day above Nome Creek this would mean getting out to drag your boat one additional time. Increasing the number of boat drags by more than twice this amount (two times on an average day, the 44% increase in the 20% flow reduction) would represent an unreasonable change in the recreation experience.

Below Nome Creek the number of boat drags per day has gone way down. A one in five increase in boat drags now means one additional carry every 2 days, while a 33% increase means one and one half, or for the sake of clarity "no more than two," additional carries in 2 days. It's probably safe to conclude that boaters would prefer the smaller increase, but the line is not clear. The jump represented by the 67% increase (the 30% flow reduction) would, in our judgment, be unacceptable.

Pool Depths

Pool depths in Beaver Creek will decrease directly with decreasing discharge and indirectly as the result of adjustments in channel morphology. Pools provide primary feeding, escape cover, and resting areas for grayling. In addition, grayling winter in deep pools--particularly in the groundwater seep areas along the White Mountains.

The relative effects of reduced summer or winter low flows on pool depths are small compared to the probable effects of reduced annual peak flows. Our judgment is that overall pool depths would decrease in proportion to the 0.42-power of dominant discharge based upon the developed channel geometry relationship for mean depth. Therefore, present pool depths which average from 4-8 feet for primary pools, 3-5 feet for secondary pools, and 8-12 feet for the deepest measured pools, would all decrease by roughly 9% for a 20% reduction in annual peak flows, and by roughly 18% for a 40% reduction in annual peak flows.

Any loss of pool depth would adversely impact the overwintering survival of the total population of Beaver Creek grayling. Deep water pools, which provide prime refuge for large adult grayling, are in short supply (Webb,

1986). Fish movement between pools is difficult for adult fish during low-flow periods and is essentially impossible in winter.

Lowering water levels in pools during summer could adversely affect grayling fry. During droughts, young grayling are often trapped in shallow pools isolated from the main channel by lowering water levels (de Bruyn and McCart, 1974).

While it is beyond the scope of this project, it should be mentioned that pool depths are also generally very sensitive to sediment delivery--and often undergo substantial filling and reductions in depth when sediment delivery to streams is increased.

Active Channel Widths

Active channel widths in Beaver Creek will decrease as a result of decreased annual peak flows. Decreases in live water widths will also occur as a result of reduced mean flows. Decreases in live water width influence recreational boating by increasing problems of passage around debris blocks. Decreases in active channel width directly influence the size and quality of gravel bars, which in turn may affect camping quality and the size of the stream-based viewshed.

Active channel width adjustments are difficult to analyze because in addition to the hydrologic and geomorphic processes which enhance widths, there are important vegetation growth and succession processes which serve to reduce widths and alter the conditions of the flood flow channel. Our best judgment is that active channel widths will be reduced in proportion to the 0.4 power of dominant discharge as determined from the channel geometry relationship for top width. Using this assumption, the effect of 20% and 40% reductions in annual peak flows on point bar dimensions, side bar dimensions, and bankfull channel widths are shown in Table 17. We caution, however, that the reductions in Table 17, particularly for unvegetated bar dimensions, may be understated compared to what could occur if vegetation growth and succession could be factored into the analysis.

Table 17. Beaver Creek active channel width analysis
(Dimensions shown represent maximum values for Beaver Creek)

	Width (ft)	0.9 Width[1/] (ft)	0.8 Width[2/] (ft)	Length (ft)
Point Bars (Below Nome)	500	450	400	1300
Side Bars (Below Nome)	150	135	120	1000
Bankful Channel				
Above Nome	130	117	104	
Below Nome	250	225	200	

1/ Caused by a 20% reduction in flood flows

2/ Caused by a 40% reduction in flood flows

For the width analysis, the issue appears to be whether the reduction in width is noticeable to an average floater. Most users would probably be hard-pressed to identify a 10% reduction, but they could probably identify a 20% reduction. It is our judgment that the open gravel bars are a critical part of the recreation experience on Beaver Creek, so one should be conservative here.

Sloughs

Sloughs, which intersect the main channel of Beaver Creek, are created mostly as abandoned channels or oxbows, but also exist as infrequently used flood-flow channels and tributary channels. For the most part, they result from channel processes which occur during large flood flows. Sloughs function as important feeding and rearing areas for grayling, and provide protected resting areas during periods of very high flow. They are also excellent recreational fishing sites (Figure 20).

Figure 20. Sloughs function as important feeding and resting areas for grayling and serve as excellent recreational fishing sites.

We have no data on the frequency of adjustments which create sloughs. About all that can be deduced is that reducing flood flows--which would be represented by a lower flood-frequency relationship, would reduce the frequency of adjustments which create sloughs. Thus, there would be fewer sloughs--and possibly slough size would decrease. In addition, a higher percentage of sloughs would be in advanced successionary stages (more shallow and narrow morphometry).

If we assume that very large flows (e.g. 50- and 100-yr. floods) are largely responsible for major channel adjustments, we can say a few things about the frequency of slough formation.

1. A 20% reduction in flood flows means that the frequency of occurrence of large floods (e.g. 50-yr.) would be roughly halved (Figure 10).

2. A 10% reduction in the 50-yr. flow would result in roughly a 25% reduction in its frequency of occurrence.

3. A 40% reduction in the 50-yr. flow would result in roughly a 75% reduction in its frequency of occurrence.

This would clearly affect the rate of formation of new sloughs and the successionary stage of old sloughs. But we can't say how it would affect the total number of sloughs or amount of slough habitat.

The fish habitat implications are also not clear. Any reduction in the total number of sloughs or in the amount of suitable slough habitat would correspondingly reduce grayling population and the quality and quantity of recreational fishing sites.

Bed Sediment Sizes

Beaver Creek bed material sizes showed no significant trends with increasing bankfull discharge. Average sizes were:

D-16 = 28mm
D-50 = 59mm
D-85 = 90mm

Bed sediment size influences the quality and stability of habitat for benthic organisms, and may influence the amount and quality of fish spawning habitat.

Generally, the effects of decreasing annual peak flows is to decrease bed material sizes. Reduced low flows and increased sediment delivery may also result in more pronounced blanketing by sand-sized sediments. Right now, our data do not suggest what the magnitude of these sediment size reductions might be. For only modest flow reductions, the effects may be small. For large flow reductions, or major increases in sediment delivery, we might expect significant reductions in bed material sizes.

No serious impacts to grayling habitat would be expected. Grayling utilize a wide range of substrate types, from sandy riffle areas to mud-bottomed backwater areas (Armstrong, 1982).

Wetted Perimeters

Wetted perimeters decrease with decreasing flow. Wetted perimeter often serves as an index to benthic food production, fish crowding, and stress. The inflection point in a wetted perimeter vs. discharge plot may indicate a discharge below which adverse fish effects may occur (Alaska Dept. of Natural Resources, 1985).

Information on wetted perimeter vs. dishcharge is provided for all cross sections (Appendix B). In Figures 21 to 27 wetted perimeter is plotted as a function of discharge for selected representative cross sections. Mean August discharge and bankfull discharge is also noted on the plots.

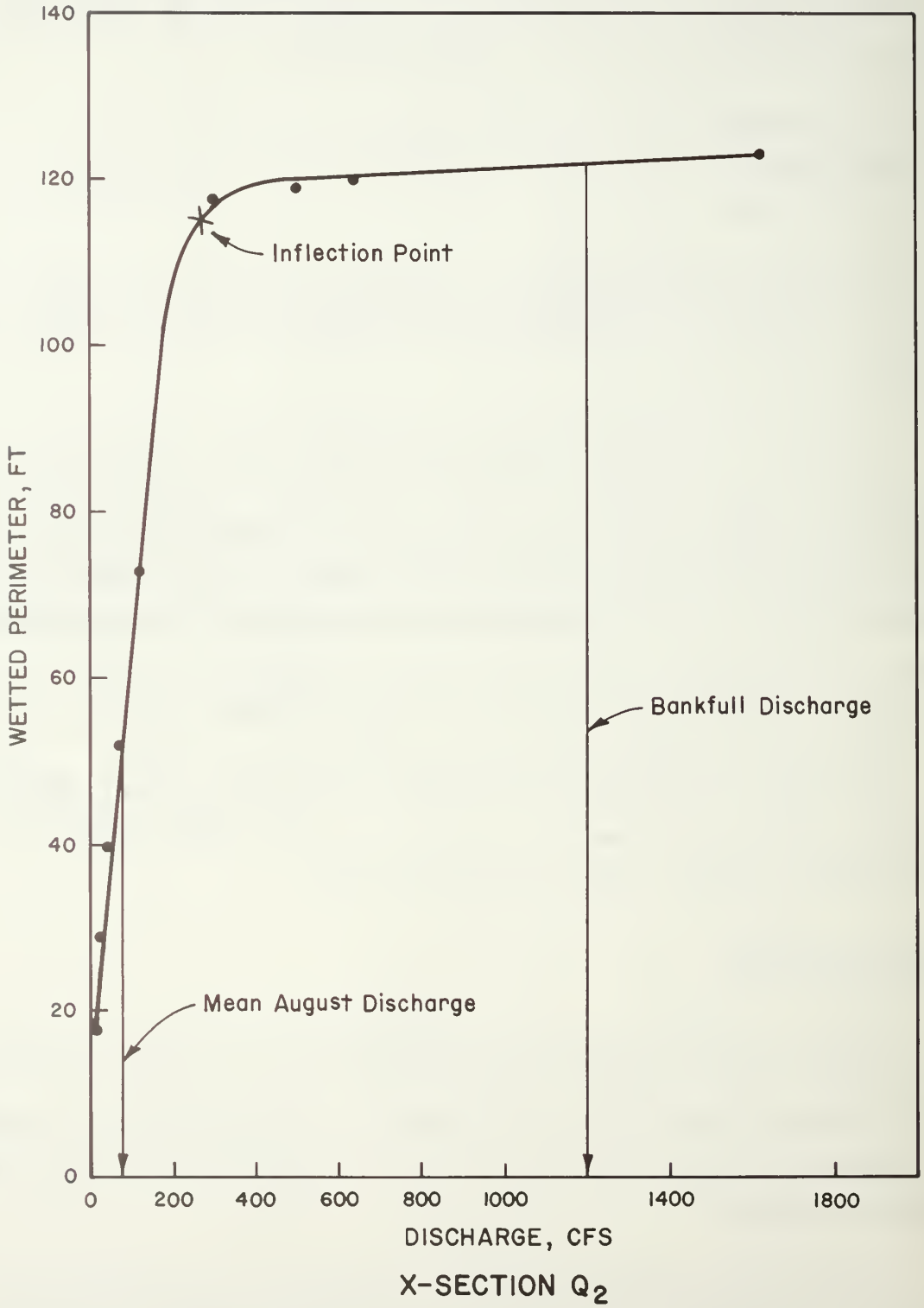

Figure 21. Relationship between Beaver Creek discharge and wetted perimeter at X-section Q_2.

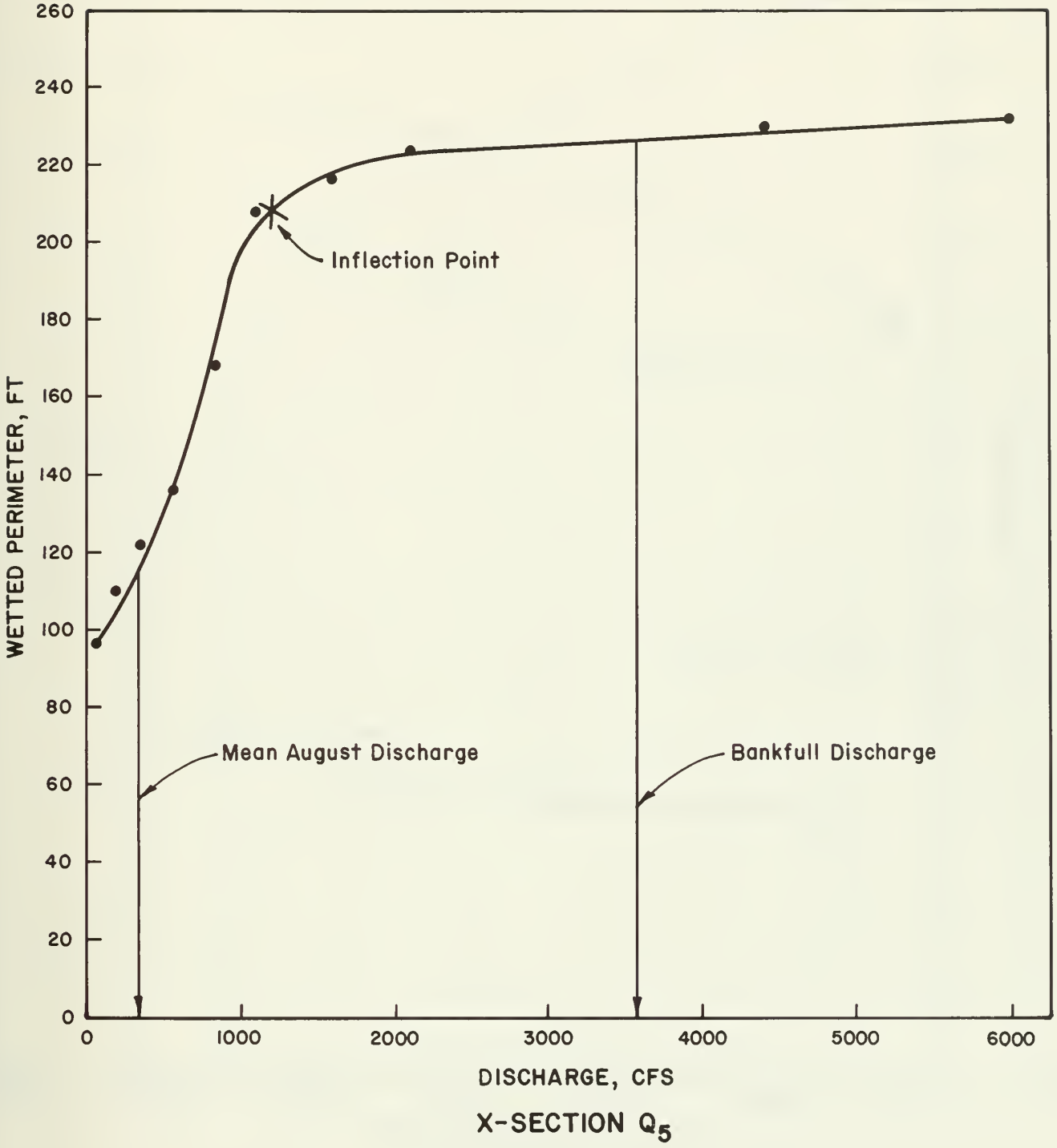

Figure 22. Relationship between Beaver Creek discharge and wetted perimeter at X-section Q_5.

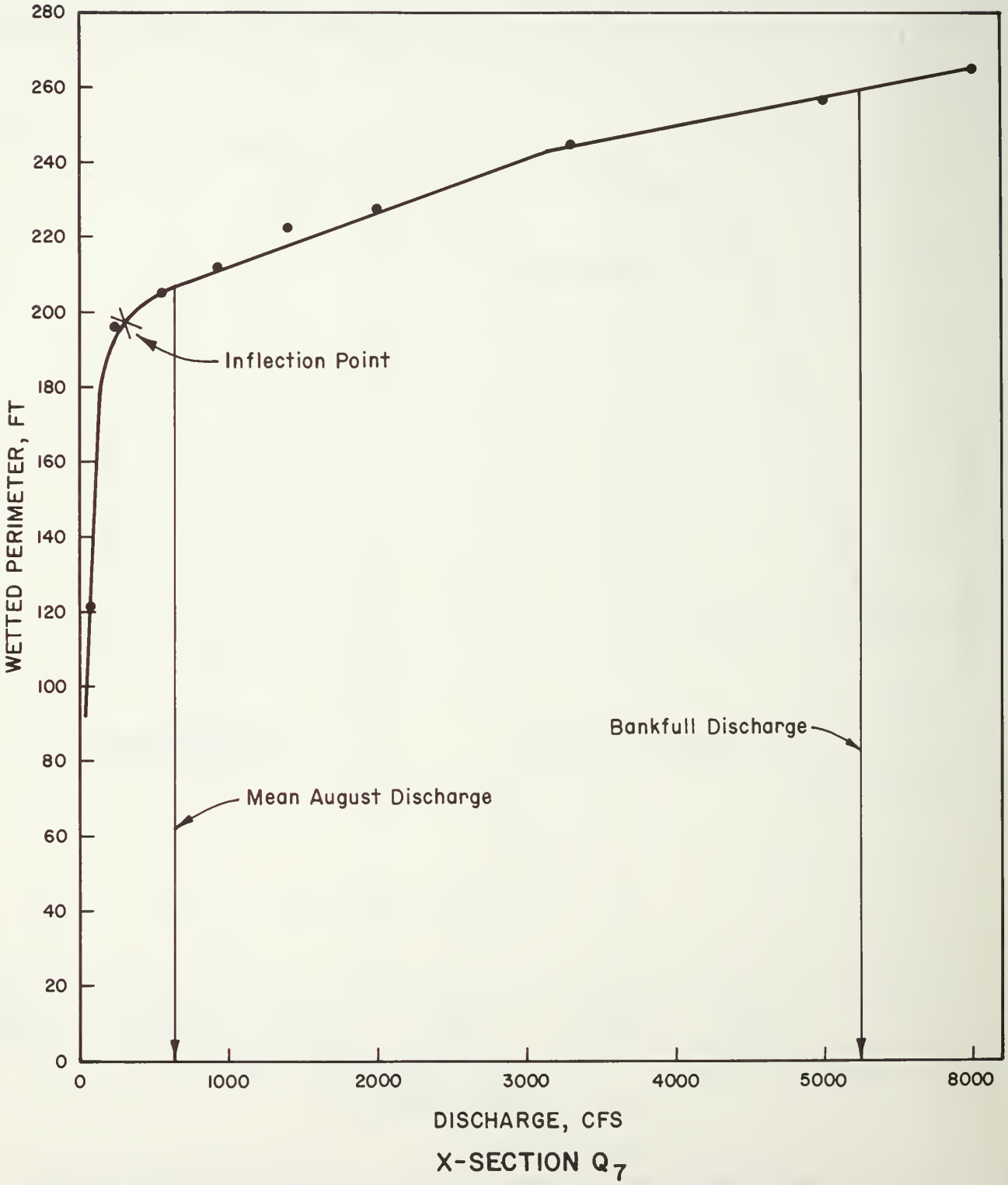

Figure 23. Relationship between Beaver Creek discharge and wetted perimeter at X-section Q_7.

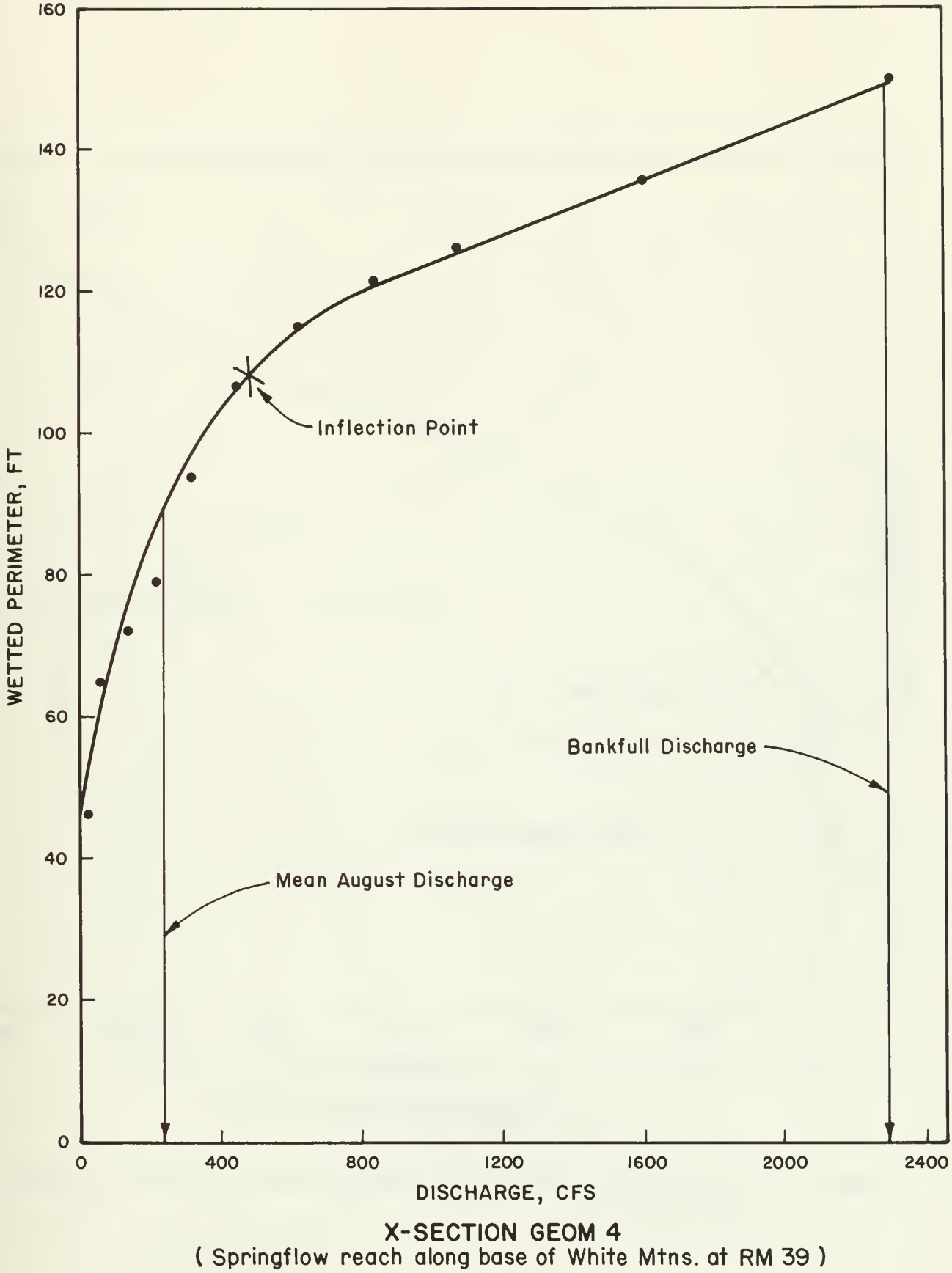

Figure 24. Relationship between Beaver Creek discharge and wetted perimeter at X-section G_4.

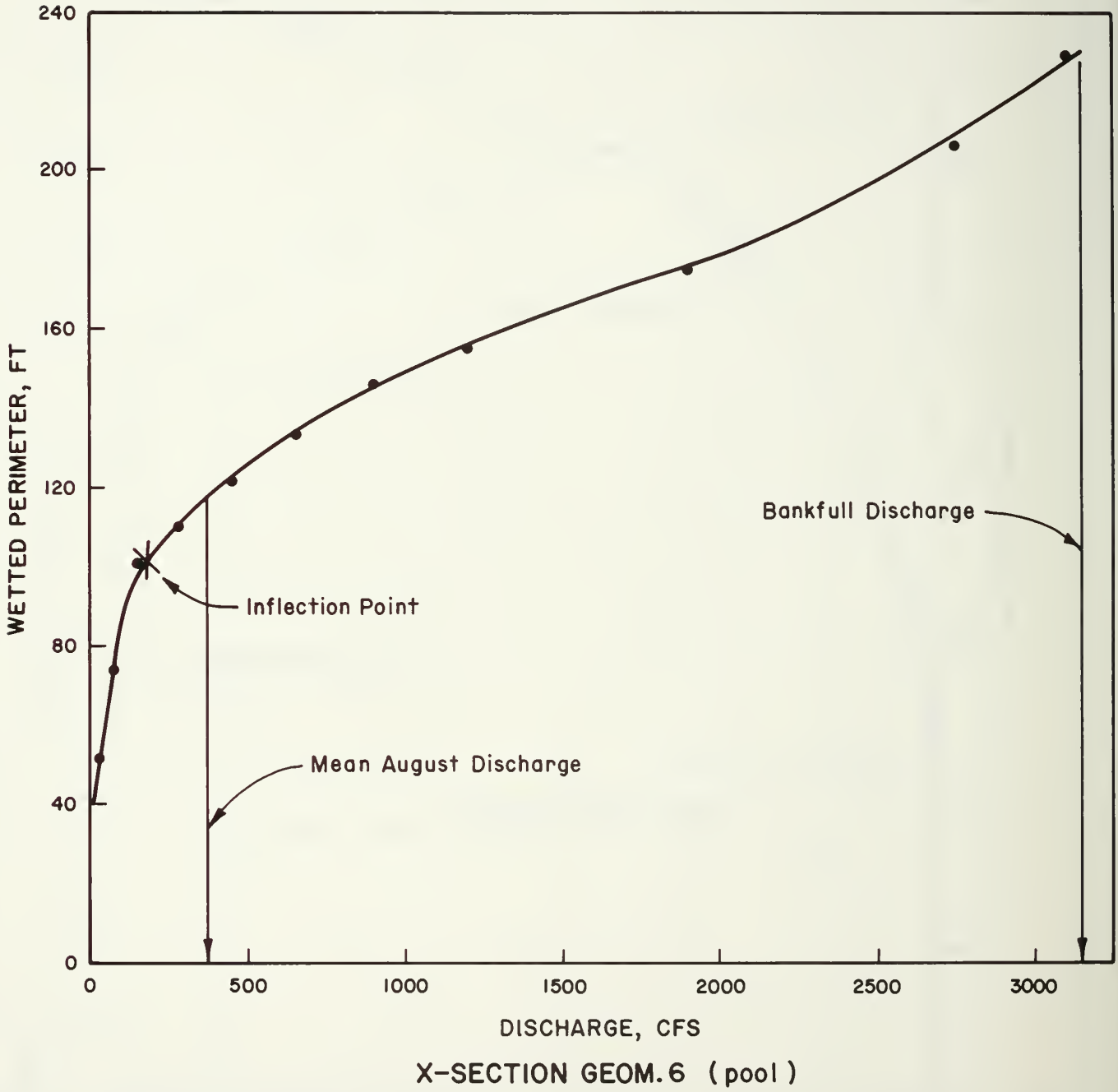

Figure 25. Relationship between Beaver Creek discharge and wetted perimeter at X-section G_6.

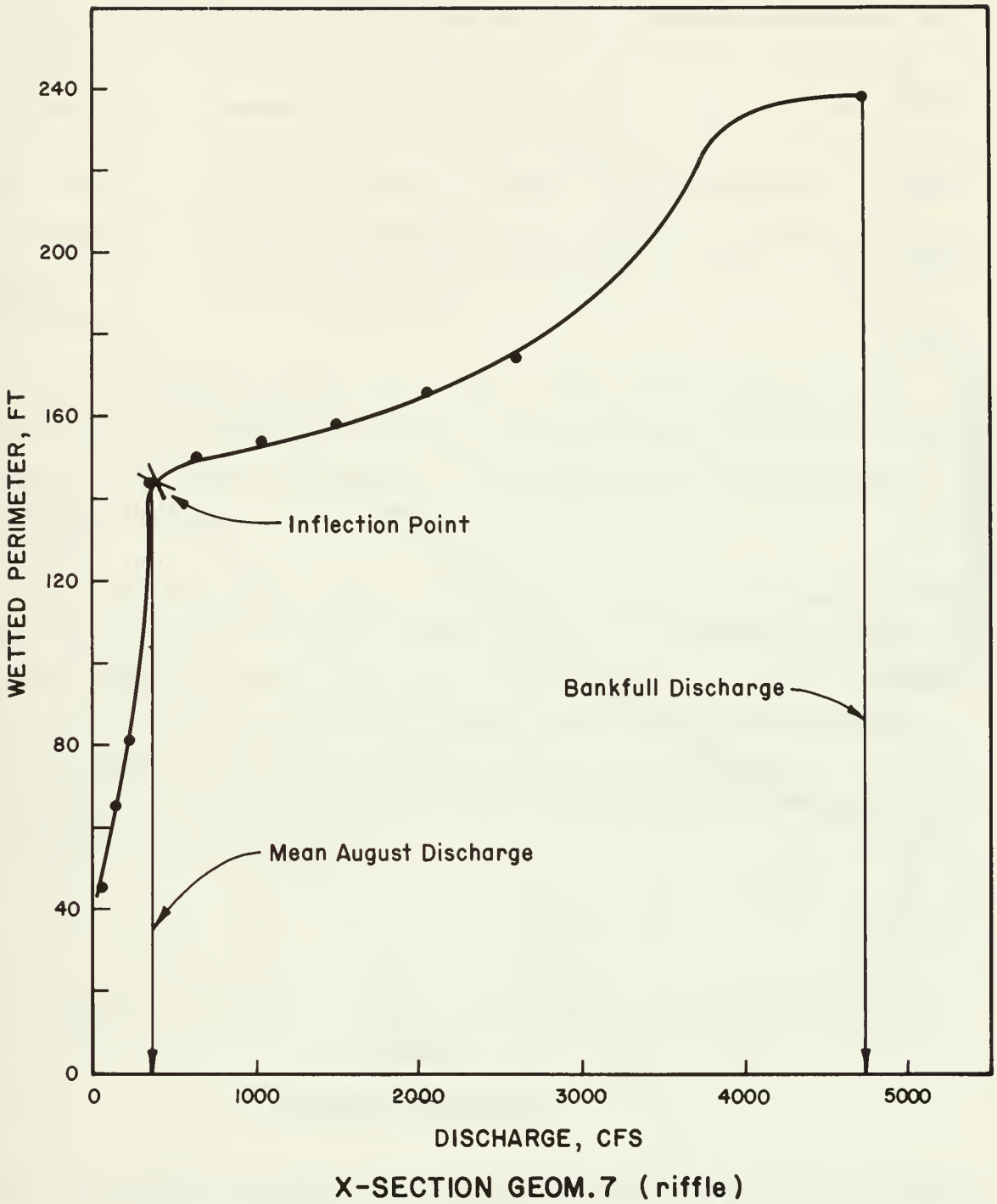

Figure 26. Relationship between Beaver Creek discharge and wetted perimeter at X-section G_7.

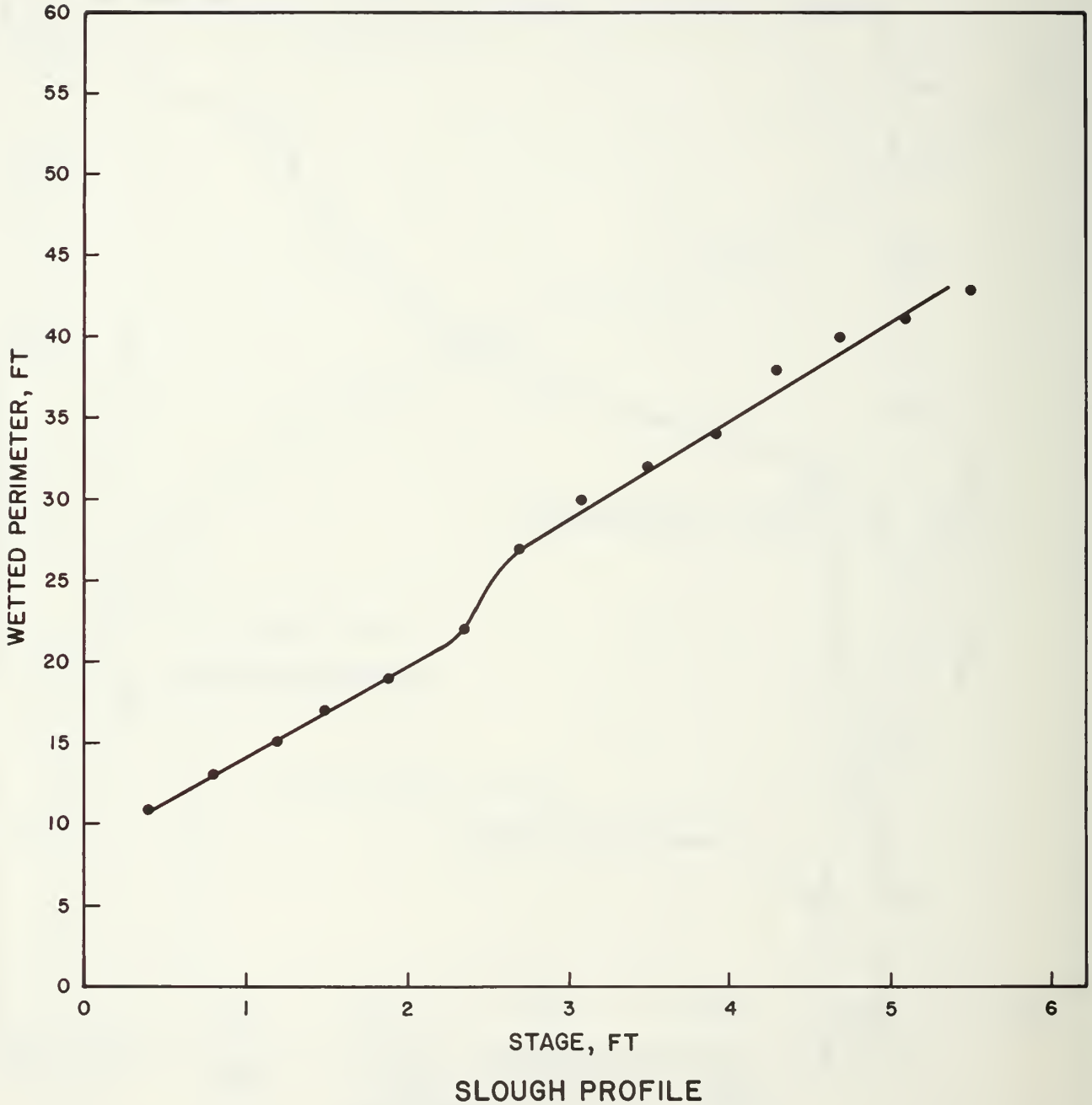

Figure 27. Relationship between Beaver Creek discharge and wetted perimeter at X-section $Q_{5/6}$ slough profile).

Both for the plotted relationships, and the unplotted relationships expressed in the data in Appendix B, it is noted that the inflection point in the discharge vs. wetted perimeter relationship is always at a point considerably less than the bankfull discharge, and is often very roughly approximated by mean summer (July-September) flows. In several cases, mean summer flows are already lower than flows associated with the inflection point. This analysis suggests that any reduction in mean summer low flows will dramatically decrease the amount of wetted perimeter, whereas summer flows in excess of mean flows add proportionately much less potential wetted perimeter.

A rapid loss of wetted perimeter would reduce main channel use by juvenile and adult grayling. The loss of wetted perimeter that could be tolerated is not conclusively known, because data on grayling population densities are lacking.

The one cross section profile of a slough did not exhibit any marked inflection points in the stage vs. wetted perimeter relationship (Figure 27). This means that wetted perimeter in this slough is linearly dependent upon stage and there are no critical points below which wetted perimeter rapidly decreases. However, we did not consider this slough to be representative, in terms of morphology or grayling habitat, of the majority of sloughs in Beaver Creek.

Instream Flow Recommendations

The instream flow recommendations which follow are the minimum flows which we believe will maintain the flow-dependent river values identified in designating Beaver Creek a National Wild River. They were quantified by combining the preceding instream flow and hydrologic analyses, and are presented in Tables 18 and 19, and Figure 28.

Recommended winter base flows for the November to April period are presented in Table 18. Those flows represent 100% of the flow which generally occurs during that period. The winter period is an extremely low-flow period and is believed to be a critical period for fish survival. Even small reductions in winter period flows could be expected to be highly detrimental to fish survival. In keeping with this concern, it is important to recognize that groundwater seeps along the base of the White Mountains may be particularly important to the winter flow-fish survival issue. It is important that land uses in the White Mountains be managed to avoid any impacts on the groundwater system in that region.

Table 18. Recommended Beaver Creek instream flows, cfs, November-April

	Nov.	Dec.	Jan.	Feb.	Mar.	April
Wild River Mile 0						
Present	1.3	.22	.1	.1	.1	6.6
Needed	1.3	.22	.1	.1	.1	6.6
Wild River Mile 35						
Present	5.9	1.0	.44	.42	.42	29
Needed	5.9	1.0	.44	.42	.42	29
Wild River Mile 112						
Present	13	1.9	.93	.88	.88	60
Needed	13	1.9	.93	.88	.88	60

Recommended instream annual peak flows for the May-June high flow period are given in Figure 28. These flows represent a 20% reduction in the Beaver Creek flood-frequency relationship and would be achieved by monitoring 80% of the instantaneous flow instream during this period. The May-June period is critical for the maintenance of stream morphology. Peak flow reductions in excess of 20% would, in our judgment, adversely affect wild river values dependent upon active channel width, gravel bar size, pool and riffle depth, and the frequency of slough occurrence. We must stress that high flows are necessary for maintaining pool sizes and depths and little reduction in pool habitat for grayling can be tolerated without affecting that resource. (The 20% reduction in flood peaks would result in roughly a 9% reduction in maximum pool depths. Additional depth reductions would be unacceptable). In addition to its influence on pool depths, peak flow reductions in excess of 20% would cause a narrowing of gravel bars and encourage encroachment of vegetation. This would cause a perceptible narrowing of vistas and would reduce the quality and availability of campsites. (A 20% reduction in flood peaks would correspond to roughly a 9% reduction in active channel width).

Recommended instream flows for the July-October period are given in Table 19. These flows represent 90% of the mean monthly flow or 90% of the instantaneous flow, whichever is least. It is our judgment that flow reductions in excess of recommended values would have unacceptable adverse effects on recreational opportunities on the river. In particular, the number of incidents requiring boat portaging would become unacceptably large, and float times would become excessively long. In addition, any greater reductions in wetted perimeter would decrease pool depths, reduce fish food production, cause crowding, and adversely affect the arctic grayling fishery. Water quality could also be affected by reductions in summer-fall mean flows.

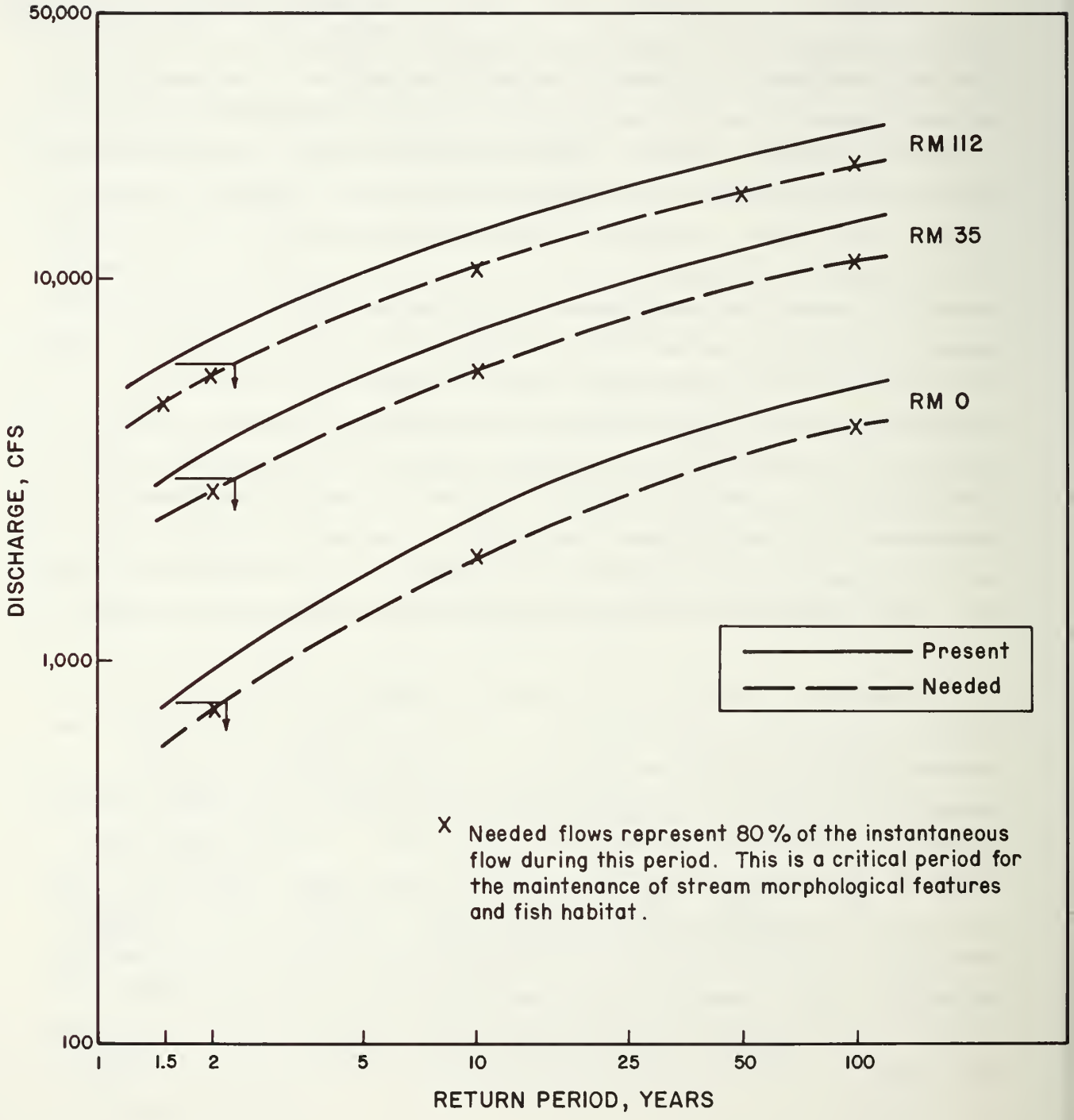

Figure 28. Recommended instream peak flows for the May-June period.

Table 19. Recommended Beaver Creek instream flows, cfs, July-October

	July	Aug.	Sept.	Oct.
Wild River Mile 0				
Present	77	71	67	13
Needed	69	64	60	12
Wild River Mile 35				
Present	346	314	295	55
Needed	311	282	266	50
Wild River Mile 112				
Present	696	649	609	115
Needed	626	584	548	104

A summary of the effects of the maximum acceptable flow reductions on monthly water yields, effective discharge, and hydraulic geometry variables are summarized in Table 20. It is judged that none of these effects will alter basic flow-dependent values to the point where the outstandingly remarkable wild river character of Beaver Creek will be lost.

Table 20. Summary of effects of maximum acceptable flow reductions on water yield, effective discharge, and hydraulic geometry in Beaver Creek

I. Water Yield, acre-feet per month (average):

Reduction	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
WRM 0	0	0	0	0	0	0	2,800	1,900	430	420	400	77
WRM 35	0	0	0	0	0	0	12,100	8,200	2,000	1,900	1,700	330
WRM 112	0	0	0	0	0	0	25,100	17,000	4,100	3,900	3,600	680

II. Effective (Bankfull) Discharge:
- Reductions in Peak = 20%
- Change in Recurrence of Former Bankfull Flow:
  1.5 yr. Increased to 2.2 yr.

III. Hydraulic Geometry:
- Bankfull width: reduce 9%
- Average depth: reduce 9%
- Wetted perimeter: reduce 9%
- Average velocity: reduce 13%
- Bed material, D_{50}: reduce (unknown)
- Sinuosity: very subtle reductions
- Slope: very subtle increases
- Lateral Adjustment: very subtle reductions in frequency and rate

ADDITIONAL RECOMMENDATIONS

1. The Team recommends that BLM file an application with the Alaska DNR for an instream flow reservation in Nome Creek to protect recreational values. Nome Creek is used as an access route and put-in location by Beaver Creek boating parties. Flows sufficient to allow canoes and inflatable rafts to pass, with minimal boat dragging to Beaver Creek, should be determined for Nome Creek. Because both access and put-in locations may change over time due to road improvements in Nome Creek, the reservation should be quantified at several points along lower Nome Creek.

2. The Team recommends implementation and partial funding of a USGS-Fairbanks proposal to reactivate the Hess Creek streamgage and establish correlating flows for Beaver and Birch Creeks. Continuation of the gage (presently has about a 10-year record) would provide for high-quality regional data, which could be used to develop estimated records for other interior streams. The USGS proposal is included as Appendix C.

3. The protection of water quality is one of the specific purposes of the Wild and Scenic Rivers Act. It is incumbent upon BLM to insure that the existing water quality on Beaver Creek is maintained, utilizing every State and Federal legal mechanism available. The natural avenues through which water quality standards should be enforced are the Clean Water Act, the Federal Land Policy and Management Act, and the 1872 Mining Law (including 3809 regulations).

4. An intensified study on the fish population, primarily grayling, is needed to determine species composition and population densities:

   a. Determine age and growth characteristics and their relation to mining and other land use activities. These data will provide a measure for making analyses and assessments of impacts.

   b. Radio-tag several large size grayling ($\geq$17 in.) to ascertain spawning, migration routes, and overwintering.

c. Measure the recreational fishing impacts on the population of grayling in Beaver Creek. Use a creel census technique for gathering these data.

5. A streamflow monitoring strategy should be devised and implemented in the Beaver Creek National Wild River. Direct measurements of Beaver Creek flows should be correlated with regional data and the results used to substantiate and more closely define instream flow needs in Beaver Creek.

Acknowledgements

We wish to thank Ron Huntsinger and Tom Dew for project support, Joe Webb for consultation on grayling habitat, Karla Knoop for data reduction and analysis, Bob Burrows (USGS-Fairbanks) for hydrologic consultation, and June Johnson for word processing.

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APPENDIX A

Application for

Instream Flow Reservation

STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF LAND AND WATER MANAGEMENT

Northcentral District
4420 Airport Way
Fairbanks, Alaska 99701
(907) 479-2243

Southcentral District
Pouch 7-005
Anchorage, Alaska 99510
(907) 276-2653

Southeastern District
230 S. Franklin, Room 407
Juneau, Alaska 99801
(907) 465-3400

OFFICE USE ONLY

LAS

APPLICATION FOR RESERVATION OF WATER

INSTRUCTIONS: This is an application to reserve a specific instream flow or level of water under AS 46.15.145 and 11 AAC 93.141-147. This application must be filled out completely and all requested attachments submitted with it. Failure to complete all parts of the application may result in return of the application. Attach extra pages to fully answer questions. If a report is attached as part of this application, indicate appropriate page numbers following each question. Submit this application to the district in which the proposed reservation is located (identified above). Please type or print in ink.

1. Full legal name of applicant(s): United States of America c/o Bruce Landon, United States Department of Justice

2. Mailing Address: Fairbanks District Office, 1541 Gaffney Road,

   City: Fairbanks State: Alaska Zip: 99703

   Business Phone: (907) 271-5452 Home Phone: _____

3. Name of the stream or water body in which water is proposed to be reserved:

   Beaver Creek

4. Location of the proposed reservation of water:

   (a) List ALL sections, townships, ranges and meridians from the beginning to the end of the stream segment and for all parts of the lake or waterbody in which water is requested to be reserved. (Attach extra pages if needed.)

   BEAVER CREEK, ALASKA. The segment of the main stem from the vicinity of the present confluence of the Bear and Champion Creeks downstream to its exit from the northeast corner of Section 1. T11N, R5E.

   (See attached pages)

10-1151 (11/83)

Legal Description - BEAVER CREEK NATIONAL WILD RIVER

The following lands are included within the Beaver Creek National Wild River Boundary. All descriptions are from Fairbanks Meridian, Alaska. River bottom acreages have been subtracted for each section, based upon water and island acreages given in Master Title Plats. The legal descriptions are based on the unsurveyed 1 inch = 1 mile scale BLM boundary maps.

T. 7 N., R. 4 E., Unsurveyed

Section 19	SE¼NE¼, S½;
Section 20	SW¼NW¼, W½SW¼;
Section 29	NW¼NW¼;
Section 30	NE¼NE¼, W½NE¼, NW¼, NW¼SW¼.

T. 7 N., R. 3 E., Unsurveyed

Section 24	E½SE¼, SW¼SE¼;
Section 25	NE¼, E½NW¼, SW¼NW¼, S½;
Section 26	SE¼NE¼, S½;
Section 27	S½SE¼;
Section 29	S½S½;
Section 30	S½S½;
Section 31	All;
Section 32	All;
Section 33	All;
Section 34	All;
Section 35	N½N½, S½NW¼, N½SW¼, SW¼SW¼;
Section 36	N½N½.

T. 6 N., R. 3 E., Unsurveyed

Section 2	W½W½;
Section 3	N½N½, SE¼NE¼, E½SE¼;
Section 4	NE¼NE¼.

T. 7 N., R. 2 E., Unsurveyed

Section 26	S½SW¼, SW¼SE¼;
Section 27	SE¼SE¼;
Section 31	SE¼NE¼, S½S½, NE¼SE¼;
Section 32	S½N½, S½;
Section 33	S½N½, S½;
Section 34	NE¼, E½NW¼; SW¼NW¼, S½;
Section 35	NW¼NE¼, S½NE¼, NW¼, S½;
Section 36	NE¼, E½NW¼; SW¼NW¼, S½;

T. 6 N., R. 2 E., Unsurveyed

Section 3	NW¼;
Section 4	N½,N½S½;
Section 5	N½,N½S½;
Section 6	N½,N½S½.

T. 7 N., R. 1 E., Unsurveyed

Section 6	N½NW¼,SW¼NW¼,NW¼SW¼;
Section 31	S½SW¼,SE¼;
Section 32	S½;
Section 33	S½;
Section 34	NW¼SW¼,S½S½;
Section 35	S½S½;
Section 36	S½S½.

T. 6 N., R. 1 E., Unsurveyed

Section 1	N½,N½S½;
Section 2	N½,N½S½;
Section 3	N½,SW¼,N½SE¼,SW¼SE¼;
Section 4	N½,N½S½,SE¼SE¼;
Section 5	N½,N½S½;
Section 6	N½,SW¼,N½SE¼,SW¼SE¼.

T. 7 N., R. 1 W., Unsurveyed

Section 1	N½,SW¼,N½SE¼;
Section 2	All;
Section 3	NE¼,SE¼NW¼,S½;
Section 4	SE¼SW¼,S½SE¼;
Section 9	NE¼,E½NW¼,SW¼NW¼,S½;
Section 10	All;
Section 11	N½NE¼,SW¼NE¼,W½,W½SE¼;
Section 12	NW¼NW¼;
Section 14	W½NE¼,NW¼;
Section 15	N½,SW¼,N½SE¼;
Section 16	All, except 63.36 acres of private land (USS 3227) in W½;
Section 17	SE¼SW¼,SE¼;
Section 19	NE¼NE¼,S½NE¼,SE¼SW¼,SE¼;
Section 20	All;
Section 21	N½NE¼,SW¼NE¼,W½;
Section 22	NW¼NW¼;
Section 28	SW¼NE¼,W½,W½SE¼;
Section 29	All;
Section 30	All;
Section 31	N½;
Section 32	N½,NE¼SW¼,SE¼;
Section 33	All;
Section 34	S½;
Section 35	S½;
Section 36	S½S½.

T. 6 N., R. 1 W., Unsurveyed

Section 1	N½,N½SW¼,SE¼SW¼,SE¼;
Section 2	N½,N½S½;
Section 3	N½,N½S½;
Section 4	NE¼,E½NW¼,N½SE¼.

T. 7 N., R. 2 W., Unsurveyed

Section 25	E½SE¼;
Section 36	E½NE¼.

T. 8 N., R. 1 W., Unsurveyed

Section 1	W½NW¼,SE¼NW¼,SW¼,W½SE¼;
Section 2	N½,NE¼SW¼,SE¼;
Section 11	E½E½;
Section 12	NW¼NE¼,S½NE¼,W½,SE¼;
Section 13	All;
Section 14	E½E½;
Section 24	All;
Section 25	All;
Section 34	SE¼SE¼;
Section 35	E½NE¼;SW¼NE¼,S½;
Section 36	All.

T. 8 N., R. 1 E., Unsurveyed

Section 7	SW¼SW¼;
Section 18	W½W½;
Section 19	All;
Section 20	SW¼NE¼,S½NW¼,S½;
Section 29	NW¼NE¼,W½;
Section 30	All;
Section 31	N½,SW¼,NW¼SE¼;
Section 32	NW¼NW¼.

T. 9 N., R. 1 W., Unsurveyed

Section 12	S½SE¼;
Section 13	NE¼,E½NW¼,S½;
Section 23	S½SE¼;
Section 24	All;
Section 25	N½NE¼,SW¼NE¼,W½;
Section 26	E½,E½W½;
Section 35	All;
Section 36	W½W½.

T. 9 N., R. 1 E., Unsurveyed

Section 5	N½NE¼,SW¼NE¼,W½;
Section 6	N½,E½W½,SW¼SW¼;
Section 7	All;
Section 8	NE¼NW¼,W½W½;
Section 18	N½NE¼,SW¼NE¼,NW¼N½SW¼.

T. 10 N., R. 1 E., Unsurveyed

Section 1	E½,NE½SW¼,S½SW¼;
Section 2	SE¼SE¼;
Section 11	E½NE¼,SE¼SW¼,SE¼;
Section 12	N½,SW¼,N½SE¼,SW¼SE¼;
Section 13	N½NW¼,SW¼NW¼;
Section 14	NE¼,E½NW¼,SW¼NW¼,SW¼,N½SE¼,SW¼SE¼;
Section 15	E½SE¼,SW¼SE¼;
Section 21	E½SE¼,SW¼SE¼
Section 22	NE¼,E½NW¼,SW¼NW¼,SW¼,N½SE¼,SW¼SE¼;
Section 23	NW¼,NW¼SW¼;
Section 27	N½NW½,SW¼NW¼,W½SW¼;
Section 28	E½,SE¼NW¼,SW¼;
Section 29	S½SE¼;
Section 31	S½SE¼;
Section 32	NE¼,SE¼NW¼,NE¼SW¼,S½SW¼,SE¼;
Section 33	N½NE¼,NW¼,NW¼SW¼.

T. 10 N., R. 2 E., Unsurveyed

Section 1	N½,N½S½;
Section 2	N½,N½SE¼;
Section 3	N½;
Section 4	N½,SW¼,NW¼SE¼;
Section 5	All;
Section 6	N½,N½S½,SW¼SW¼;
Section 7	NW¼NW¼.

T. 11 N., R. 2 E., Unsurveyed

Section 25	S½S½;
Section 31	S½S½;
Section 32	S½S½;
Section 33	S½N½,S½;
Section 34	E½,S½NW¼,SW¼;
Section 35	S½NE¼,NW¼NW¼,S½NW¼,S½;
Section 36	All.

T. 10 N., R. 3 E., Unsurveyed

Section 1	N½,N½S½,SW¼SW¼;
Section 2	NE¼,E½NW¼;
Section 6	N½NW¼;SW¼NW¼,NW¼SW¼;

T. 11 N., R. 3 E., Unsurveyed

Section 19	E½,E½W½;
Section 20	All;
Section 21	All;
Section 22	All;
Section 26	S½S½;
Section 27	All;
Section 28	N½,SE¼;
Section 29	All;
Section 30	E½,E½NW¼,SW¼NW¼,SW¼;
Section 31	All;
Section 32	N½NE¼,SW¼NE¼,W½,NW¼SE¼;
Section 33	NE¼,N½SE¼;
Section 34	All;
Section 35	All;
Section 36	SW¼NW¼,SW¼,S½SE¼.

T. 10 N., R. 4 E., Unsurveyed

Section 3	N½NW¼;
Section 4	N½N½,SW¼NW¼;
Section 5	N½,N½S½;
Section 6	N½,N½S½.

T. 11 N., R. 4 E., Unsurveyed

Section 13	SE¼SE¼;
Section 24	E½,SE¼SW¼;
Section 25	All;
Section 26	E½,E½NW¼,SW¼NW¼,SW¼;
Section 31	E½SW¼,SW¼SW¼,SE¼;
Section 32	E½,SE¼NW¼,SW¼;
Section 33	All;
Section 34	All;
Section 35	All;
Section 36	NW¼NE¼,N½NW¼,SW¼NW¼,NW¼SW¼.

T. 11 N., R. 5 E., Unsurveyed

Section 1	NE¼,E½NW¼,SW¼NW¼,SW¼,N½SE¼, SW¼SE¼;
Section 2	S½NE¼,NW¼,S½ except 18 acres of private land;
Section 3	S½SE¼;
Section 8	SE¼SW¼NE¼SE¼,S½SE¼;
Section 9	NE¼,E½NW¼,S½;
Section 10	All;
Section 11	NE¼NE¼,W½E½,W½;
Section 12	N½NW¼;
Section 16	N½NE¼,NW¼;
Section 17	All;
Section 18	E½NE¼,NE¼SW¼,S½SW¼,SE¼;
Section 19	N½,SW¼,N½SE¼,SW¼SE¼;
Section 20	N½,N½SW¼;
Section 30	NW¼NE¼,NW¼,NW¼SW¼.

T. 12 N., R. 5 E., Unsurveyed

Section 36	S½SE¼.

T. 11 N., R. 6 E., Unsurveyed

Section 6	W½NE¼,NW¼,NW¼SW¼.

T. 12 N., R. 6 E., Unsurveyed

Section 1	E½NE¼,SW¼NE¼,S½;
Section 2	SE¼SW¼,SE¼;
Section 11	N½,SW¼,W½SE¼;
Section 12	N½N½;
Section 14	W½NE¼,W½;
Section 15	NE¼NE¼,S½N½,S½;
Section 16	S½SE¼;
Section 19	S½SE¼;
Section 20	SE¼NE¼,S½;
Section 21	N½,N½S½,SW¼SW¼;
Section 22	W½NE¼,NW¼,NW¼SW¼;
Section 28	NW¼NW¼;
Section 29	N½NE¼,NW¼,N½SW¼,SW¼SW¼;
Section 30	E½,E½W½;
Section 31	All;
Section 32	NW¼NW¼.

T. 12 N., R. 7 E., Unsurveyed

Section 6	W½NE¼,NW¼,N½SW¼,SW¼SW¼, NW¼SE¼;
Section 7	NW¼NW¼.

(b) Describe the location of the point or points defining the boundary of the proposed reservation of water by river mile index, river mile, geographical or cultural landmark, etc., on the stream or water body. (Attach extra pages if needed.)

Beaver Creek at River Mile 0 (as defined by the point at which Beaver Creek appears on the eastern edge of the Livengood (B-1) 1:63360 Quadrangle Map) immediately downstream of the confluence of Bear and Champion Creeks to River Mile 111.5 at the eastern boundary of Section 1, T11N, R5E and below the present confluence of Beaver and Victoria Creeks.

(c) ATTACH a U.S. Geological Survey map at 1:63,360 scale, or 1:250,000 scale if 1:63,360 scale is unavailable for the area, clearly identifying the following for the proposed reservation of water:

(1) Sections, townships, ranges and meridians

(2) The stream or water body in which the reservation of water is proposed

(3) Specific point or points defining the boundary of the proposed reservation of water

(4) Permanent, temporary or planned locations of water measurement devices (such as gaging stations, weirs, staff gages)

(5) Permanent, temporary or planned bench marks

5. (a) Identify the purpose(s) of the proposed reservation of water by checking the appropriate box(es).

[X] protection of fish and wildlife habitat, migration, and propagation

[X] recreation and park purposes

[X] navigation and transportation purposes

[X] sanitary and water quality purposes

(b) Describe in detail the purpose(s) of the proposed reservation, including, when appropriate; species and life stage, type of recreation, vehicle, or water quality parameter, or other relevant information. (Attach extra page if needed.)

See report attached.

6. Is the water currently being used for the purpose(s) applied for?

[X] Yes.

[ ] No. If no, when will use for this purpose begin? Specify approximate date. _____

7. (a) Water requested to be reserved (check one):

[X] to maintain a specific instream flow rate, measured in cubic feet per second

[ ] to maintain a specific level of surface water, measured in cubic feet or acre feet

[ ] to maintain a specific surface water elevation, measured in relation to a permanent benchmark

(b) Quantify the specific amount of water requested to be reserved: Identify and quantify, as appropriate; flow rates, quantities, surface water elevations, depths, etc., as they relate to the daily durations and months of the year during which the reservation is proposed. Include any flow release schedules from projects upstream of the proposed reservation that would apply. (Attach extra pages if needed.)

See report attached.

8. Attach and submit with this application documentation or reports showing facts to support the following:

(a) The need for the proposed reservation of water, including reasons why the reservation is being requested.

See attached report.

(b) Identify and describe the methodology, data, and data analysis used to substantiate the need for and the quantity of water requested for the proposed reservation of water, including:

(1) Name and description of method used,

(2) Who conducted the study and analysis,

(See attached report)

(3) Schedule of when data collection and analysis occurred,

(4) Type(s) of instrument(s) used to collect and analyze data,

(5) Description of data and how the data was collected, including when applicable, (A) selection of stream reach, study site and transect selection, (B) flow, survey, elevation, and depth measurements, (C) pertinent physical, biological, water chemistry and socio-economic data,

(6) Description of how data was analyzed, and

(7) Maps, photos, aerial photos, calculations, and any other documents supporting this application.

9. If there are provisions for monitoring this proposed reservation of water, include the following: Monitoring plans are being developed and will be submitted to DNR when completed.

(a) Description of monitoring equipment (such as gaging stations, staff gages, weirs)
(b) Location of monitoring equipment
(c) Provisions for payment of monitoring
(d) Reporting system

10. This decree is for a reserved water right vested under Federal law. The United States concedes that this right is subject to limited review under AS 46.15.145--to the extent that such review more accurately delineates the requirements of the reserved water right. In the event that a review of this water right results in a limitation of the quantity of water necessary to satisfy the purposes of the reservation, the United States reserves the right to assert a water right whose basis is Federal law. Under no circumstances is this application to be construed as a waiver of any rights vested in the United States under Federal law.

Statements contained in this application are true and correct to the best of my knowledge.

Signed _____
Applicant(s) Full Legal Name(s)

Date _____

10-1151 (11/83)

APPENDIX B

Beaver Creek Hydraulic Geometry Tables,

Discharge Rating Curves,

Channel Cross-Section Profiles,

and Bed Sediment Size Analyses

Beaver Creek, CHANL Program: selected output
Q-1

Cross Section Data:

ABOVE ENTRY LOW PT	TAPE DIST	FORESIGHT OR VERTICAL DIST	CORRECTED HORIZONTAL DIST	ELEV. X-SECT
1	0.	8.800	0.	3.400
2	3.000	10.300	2.999	1.900
3	10.000	10.400	9.998	1.800
4	20.000	8.800	19.996	3.400
5	30.000	8.400	29.995	3.800
6	40.000	8.300	39.993	3.900
7	50.000	8.900	49.991	3.300
8	60.000	9.200	59.989	3.000
9	70.000	9.500	69.987	2.700
10	81.000	10.000	80.985	2.200
11	83.000	10.000	82.985	2.200
12	85.000	10.200	84.984	2.000
13	87.000	10.300	86.984	1.900
14	89.000	10.350	88.984	1.850
15	91.000	10.300	90.983	1.900
16	93.000	10.800	92.983	1.400
17	95.000	10.800	94.983	1.400
18	97.000	10.900	96.982	1.300
19	99.000	11.000	98.982	1.200
20	101.000	10.900	100.982	1.300
21	103.000	11.000	102.981	1.200
22	105.000	11.050	104.981	1.150
23	107.000	11.050	106.980	1.150
24	109.000	10.800	108.980	1.400
25	111.000	11.300	110.980	0.900
26	113.000	11.350	112.979	0.850
27	115.000	11.400	114.979	0.800
28	117.000	11.400	116.979	0.800
29	119.000	11.400	118.978	0.800
30	121.000	11.400	120.978	0.800
31	123.000	11.500	122.977	0.700
32	125.000	11.700	124.977	0.500
33	127.000	11.500	126.977	0.700
34	129.000	11.800	128.976	0.400
35	131.000	12.000	130.976	0.200
36	133.000	12.100	132.976	0.100
37	135.000	12.200	134.975	0.
38	137.000	12.200	136.975	0.
39	139.000	12.100	138.975	0.100
40	141.000	11.900	140.974	0.300
41	143.000	11.600	142.974	0.600
42	145.000	10.950	144.973	1.250

43	147.000	11.050	146.973	1.150
44	149.000	10.000	148.973	2.200
45	153.000	10.100	152.972	2.100
46	155.000	10.000	154.972	2.200
47	158.000	8.500	157.971	3.700
48	162.000	5.700	161.970	6.500

Rating Table, Q-1 (s=.003, n=.0505):

STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.016	0.002	2.040	0.001	2.040
0.244	0.736	0.471	1.562	9.889	0.158	9.872
0.486	3.396	0.759	4.477	13.864	0.323	13.817
0.729	7.793	0.894	8.715	21.090	0.413	20.976
0.972	15.272	0.972	15.720	33.589	0.468	33.425
1.215	27.140	1.116	24.318	42.202	0.576	40.533
1.457	44.526	1.222	36.433	55.176	0.660	54.804
1.700	73.881	1.480	49.909	56.699	0.880	56.237
1.943	98.188	1.517	64.732	70.899	0.913	7.976
2.185	134.542	1.626	82.737	81.638	1.013	75.792
2.428	181.343	1.745	103.947	92.302	1.126	11.980
2.671	239.904	1.888	127.091	100.268	1.268	13.982
2.914	304.034	1.995	152.393	110.652	1.377	15.984
3.156	378.189	2.098	180.256	121.366	1.485	120.089
3.399	467.180	2.218	210.606	130.431	1.615	129.016

Channel geometry at discharge measurement stage (to verify n value) (Q-1):

**********THERE ARE MULTIPLE CHANNELS AT THIS STAGE. MANNINGS EQ. MAY
NOT APPLY.*********

CROSS SECTIONAL AREA =	83.925	SQ FEET
WETTED PERIMETER =	84.815	FEET
HYDRAULIC RADIUS =	0.990	FEET
GRADIENT =	0.0030	FEET/FOOT
MANNINGS N =	0.050	
MAXIMUM DEPTH =	2.200	FEET
MEAN DEPTH =	8.311	FEET
TOP WIDTH =	10.098	FEET
MEAN VELOCITY =	1.600	FEET/SEC
DISCHARGE =	134.314	CUBIC FEET/SEC

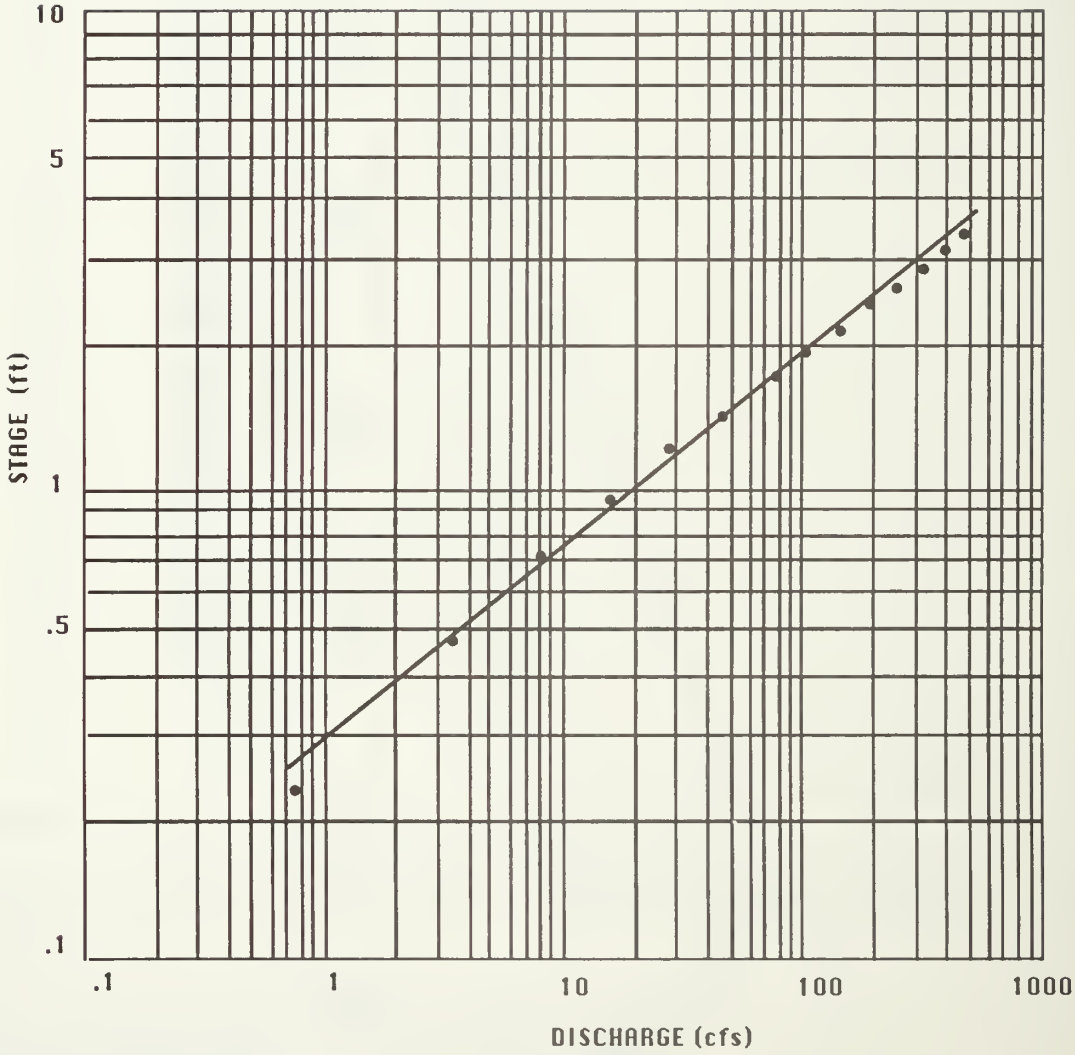
#	DISTANCE	DEPTH OF WATER
1	2.400	0.
2	2.999	0.300
3	9.998	0.400
4	12.498	0.
5	80.985	0.
6	80.985	0.000

7	82.985	0.000
8	84.984	0.200
9	86.984	0.300
10	88.984	0.350
11	90.983	0.300
12	92.983	0.800
13	94.983	0.800
14	96.982	0.900
15	98.982	1.000
16	100.982	0.900
17	102.981	1.000
18	104.981	1.050
19	106.980	1.050
20	108.980	0.800
21	110.980	1.300
22	112.979	1.350
23	114.979	1.400
24	116.979	1.400
25	118.978	1.400
26	120.978	1.400
27	122.977	1.500
28	124.977	1.700
29	126.977	1.500
30	128.976	1.800
31	130.976	2.000
32	132.976	2.100
33	134.975	2.200
34	136.975	2.200
35	138.975	2.100
36	140.974	1.900
37	142.974	1.600
38	144.973	0.950
39	146.973	1.050
40	148.973	0.000
41	152.972	0.100
42	154.972	0.000
43	154.972	0.

Channel Geometry at Bankfull Stage (Q-1):

```
*********THERE ARE MULTIPLE CHANNELS AT THIS  STAGE.     MANNINGS
EQ. MAY
NOT APPLY.*********

CROSS SECTIONAL AREA = 210.606  SQ FEET
WETTED PERIMETER =     130.431  FEET
HYDRAULIC RADIUS =       1.615  FEET
GRADIENT =               0.0030 FEET/FOOT
MANNINGS N =             0.050
MAXIMUM DEPTH =          3.399  FEET
MEAN DEPTH =             1.632  FEET
TOP WIDTH =            129.016  FEET
MEAN VELOCITY =          2.218  FEET/SEC
DISCHARGE =            467.180  CUBIC FEET/SEC
```

CHANNEL CROSS SECTION, BEAVER CREEK - Q 1



INDIRECT RATING CURVE, BEAVER CREEK, Q 1

Beaver Creek, CHANL Program: selected output
Q-2

Cross Section Data:

ABOVE ENTRY LOW PT	TAPE DIST	FORESIGHT OR VERTICAL DIST	CORRECTED HORIZONTAL DIST	ELEV. X-SECT
1	0.	8.300	0.	4.300
2	0.900	10.000	0.900	2.600
3	1.000	12.500	1.000	0.100
4	5.000	12.500	5.000	0.100
5	10.000	12.600	10.000	0.
6	15.000	12.200	15.000	0.400
7	20.000	11.900	20.000	0.700
8	25.000	11.400	25.000	1.200
9	30.000	10.900	30.000	1.700
10	35.000	10.800	35.000	1.800
11	40.000	10.850	40.000	1.750
12	45.000	10.750	45.000	1.850
13	50.000	10.600	50.000	2.000
14	55.000	10.600	55.000	2.000
15	60.000	10.700	60.000	1.900
16	65.000	10.600	65.000	2.000
17	70.000	10.250	70.000	2.350
18	75.000	10.250	75.000	2.350
19	80.000	10.450	80.000	2.150
20	85.000	10.500	85.000	2.100
21	90.000	10.950	90.000	1.650
22	95.000	11.450	95.000	1.150
23	100.000	11.800	100.000	0.800
24	105.000	11.700	105.000	0.900
25	110.000	11.350	110.000	1.250
26	115.000	11.100	115.000	1.500
27	117.500	10.000	117.500	2.600
28	117.750	8.900	117.750	3.700
29	118.000	8.100	118.000	4.500

Rating Table, Q-2 (s=.0029, n=.03165):

STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.016	0.000	0.063	0.000	0.062
0.308	2.410	0.887	2.717	13.072	0.208	12.859
0.615	10.188	1.386	7.353	18.125	0.406	17.606
0.922	21.331	1.540	13.854	29.151	0.475	21.255
1.229	43.518	1.787	24.356	41.001	0.594	24.338
1.536	78.546	2.044	38.429	52.874	0.727	27.421
1.843	118.752	2.113	56.200	73.561	0.764	43.741
2.150	179.781	2.163	83.101	104.994	0.791	102.723
2.458	292.291	2.500	116.916	118.913	0.983	116.270
2.765	454.005	2.973	152.707	119.764	1.275	116.724
3.072	643.001	3.410	188.586	120.426	1.566	116.957
3.379	856.876	3.816	224.536	121.089	1.854	117.189
3.686	1094.041	4.199	260.557	121.751	2.140	117.421
3.993	1353.188	4.562	296.653	122.420	2.423	117.679
4.300	1633.301	4.907	332.828	123.089	2.704	117.937

Channel Geometry at measured stage (verifies n value) (Q-2):

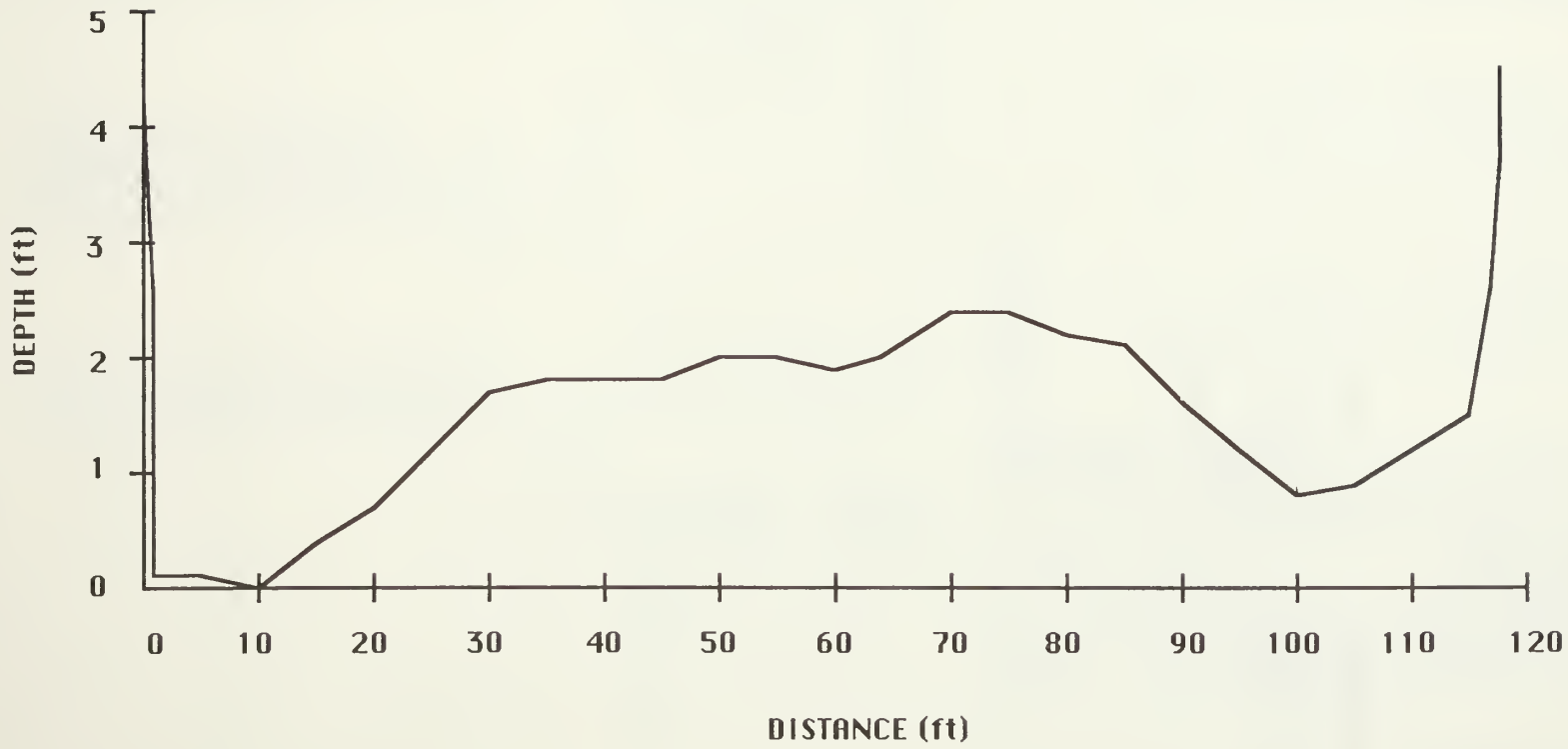
CROSS SECTIONAL AREA =	133.500	SQ FEET
WETTED PERIMETER =	119.409	FEET
HYDRAULIC RADIUS =	1.118	FEET
GRADIENT =	0.0029	FEET/FOOT
MANNINGS N =	0.032	
MAXIMUM DEPTH =	2.600	FEET
MEAN DEPTH =	1.145	FEET
TOP WIDTH =	116.600	FEET
MEAN VELOCITY =	2.724	FEET/SEC
DISCHARGE =	363.597	CUBIC FEET/SEC

#	DISTANCE	DEPTH OF WATER
1	0.900	0.
2	1.000	2.500
3	5.000	2.500
4	10.000	2.600
5	15.000	2.200
6	20.000	1.900
7	25.000	1.400
8	30.000	0.900
9	35.000	0.800
10	40.000	0.850
11	45.000	0.750
12	50.000	0.600
13	55.000	0.600
14	60.000	0.700
15	65.000	0.600
16	70.000	0.250

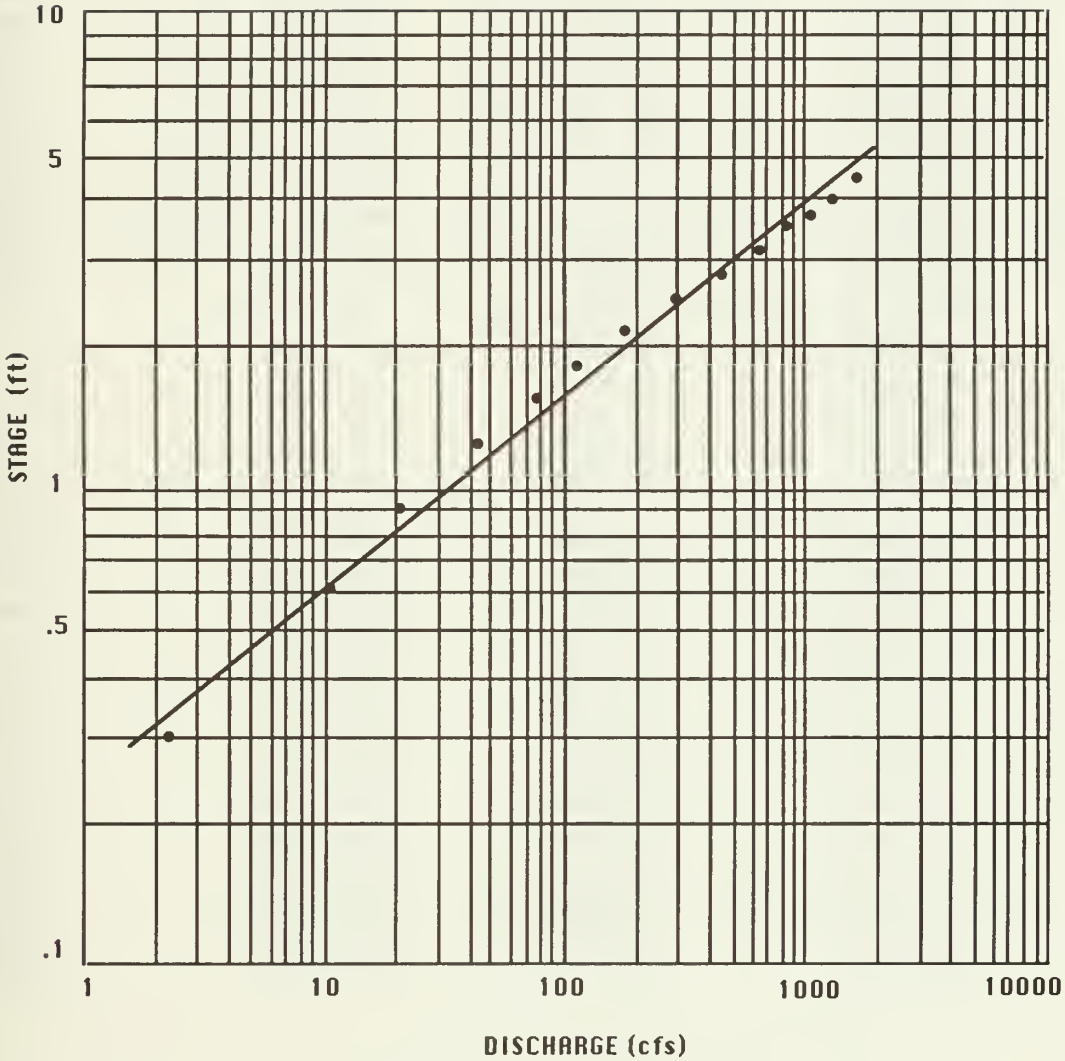
17	75.000	0.250
18	80.000	0.450
19	85.000	0.500
20	90.000	0.950
21	95.000	1.450
22	100.000	1.800
23	105.000	1.700
24	110.000	1.350
25	115.000	1.100
26	117.500	0.

Channel Geometry at Bankfull Stage (Q-2):

CROSS SECTIONAL AREA =	262.217	SQ FEET
WETTED PERIMETER =	121.782	FEET
HYDRAULIC RADIUS =	2.153	FEET
GRADIENT =	0.0029	FEET/FOOT
MANNINGS N =	0.032	
MAXIMUM DEPTH =	3.700	FEET
MEAN DEPTH =	2.233	FEET
TOP WIDTH =	117.432	FEET
MEAN VELOCITY =	4.216	FEET/SEC
DISCHARGE =	1105.503	CUBIC FEET/SEC



CHANNEL CROSS SECTION, BEAVER CREEK - Q2



INDIRECT RATING CURVE - BEAVER CREEK, Q 2

Beaver Creek, CHANL Program: selected output
Q-3

Cross Section Data:

ABOVE ENTRY LOW PT	TAPE DIST	FORESIGHT OR VERTICAL DIST	CORRECTED HORIZONTAL DIST	ELEV. X-SECT
1	0.	0.	0.	2.400
2	16.000	0.	16.000	2.400
3	25.000	0.500	25.000	1.900
4	30.000	0.950	30.000	1.450
5	35.000	1.000	35.000	1.400
6	40.000	1.300	40.000	1.100
7	45.000	1.600	45.000	0.800
8	50.000	1.800	50.000	0.600
9	55.000	2.000	55.000	0.400
10	60.000	2.200	60.000	0.200
11	65.000	2.200	65.000	0.200
12	70.000	2.300	70.000	0.100
13	75.000	2.400	75.000	0.
14	80.000	2.400	80.000	0.
15	85.000	2.300	85.000	0.100
16	90.000	2.200	90.000	0.200
17	95.000	2.100	95.000	0.300
18	100.000	2.100	100.000	0.300
19	105.000	1.900	105.000	0.500
20	110.000	1.800	110.000	0.600
21	115.000	1.800	115.000	0.600
22	120.000	1.700	120.000	0.700
23	125.000	1.600	125.000	0.800
24	130.000	1.700	130.000	0.700
25	135.000	1.600	135.000	0.800
26	140.000	1.500	140.000	0.900
27	145.000	1.500	145.000	0.900
28	150.000	1.400	150.000	1.000
29	155.000	1.100	155.000	1.300
30	160.000	0.900	160.000	1.500
31	165.000	0.700	165.000	1.700
32	170.000	0.	170.000	2.400

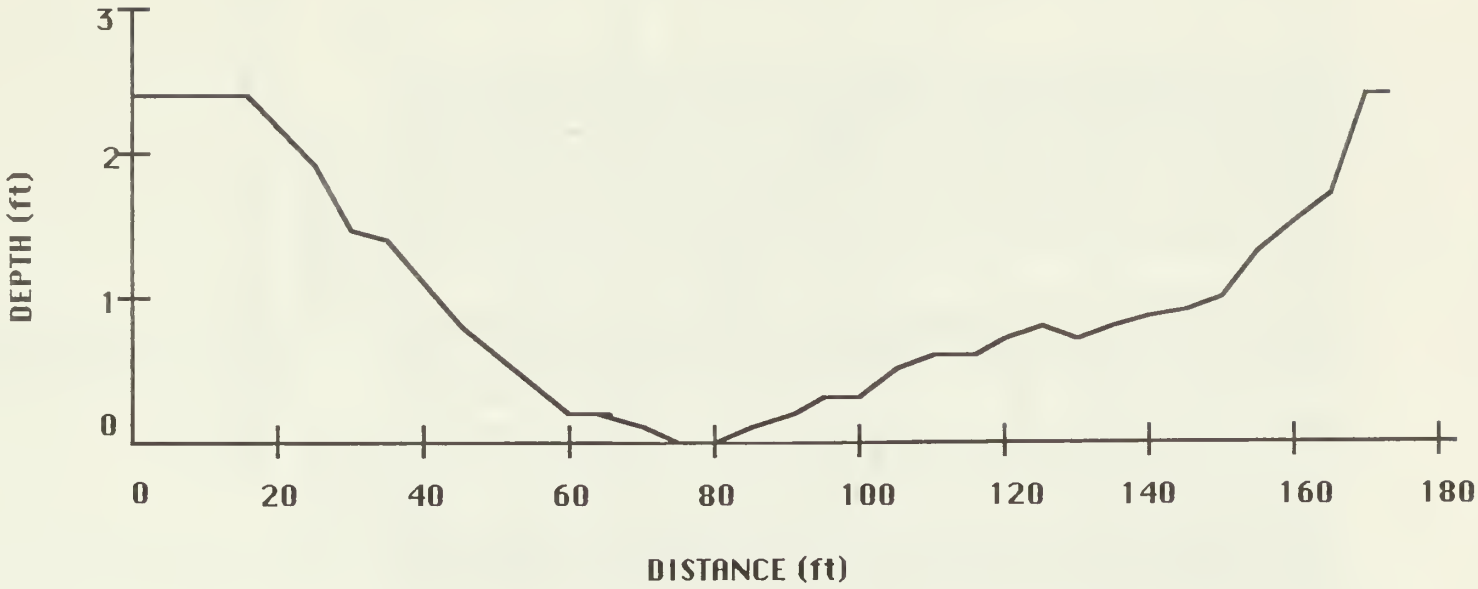
Rating Table, Q-3 (s=.0029, n=.04675):

STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.017	0.005	5.100	0.001	5.100
0.172	0.897	0.382	2.347	22.238	0.106	22.235
0.344	4.606	0.556	8.280	44.694	0.185	44.685
0.515	13.096	0.785	16.674	53.644	0.311	53.629
0.686	24.738	0.903	27.396	71.501	0.383	71.480
0.858	41.735	0.998	41.809	93.878	0.445	93.850
1.029	67.886	1.141	59.500	109.339	0.544	109.303
1.200	104.619	1.329	78.718	115.061	0.684	115.015
1.372	147.775	1.494	98.937	121.381	0.815	121.325
1.543	194.750	1.612	120.806	132.178	0.914	132.114
1.715	253.356	1.760	143.972	138.119	1.042	138.042
1.886	322.454	1.921	167.894	141.266	1.188	141.170
2.057	396.903	2.063	192.436	145.494	1.323	145.381
2.229	478.128	2.196	217.716	149.819	1.453	149.689
2.400	566.259	2.323	243.735	154.144	1.581	153.997

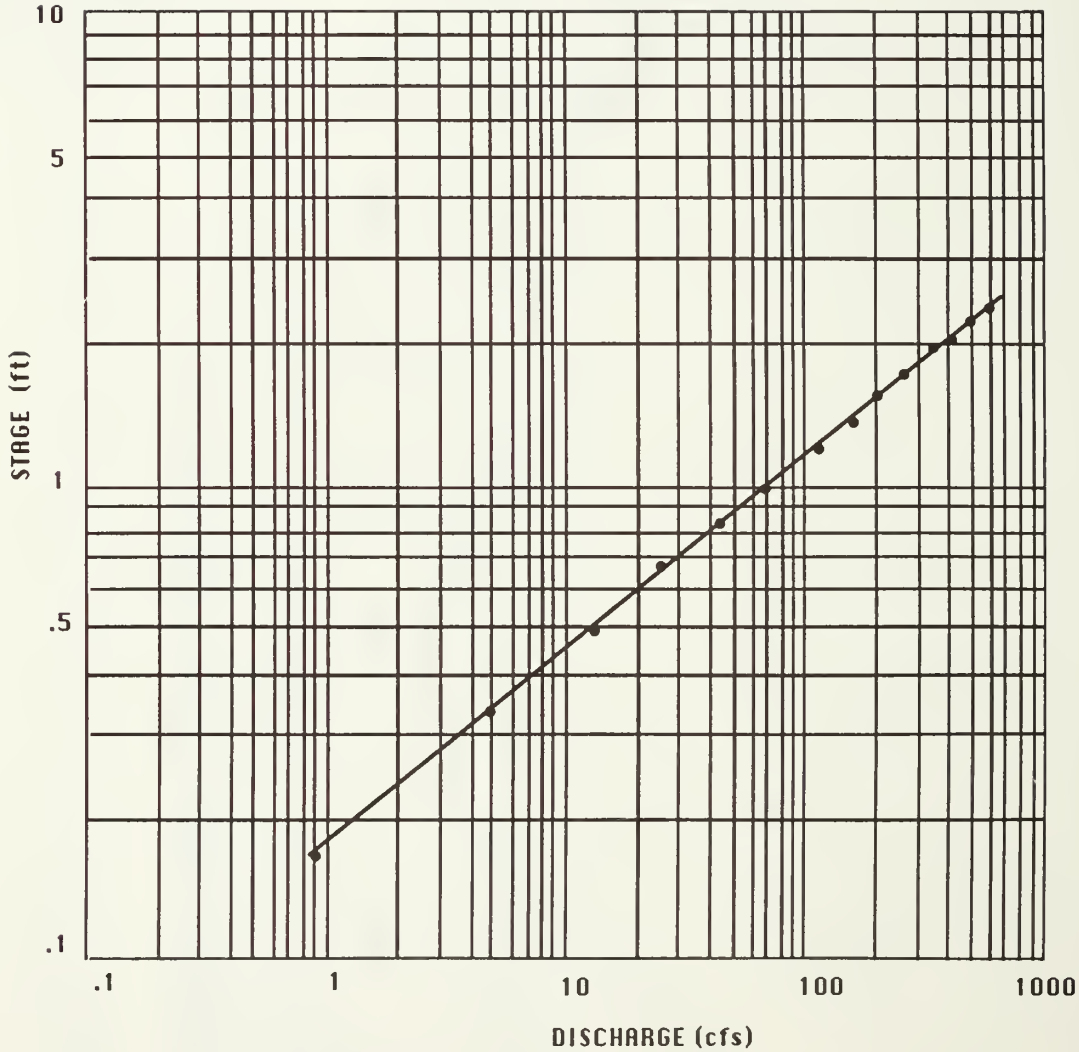
Channel Geometry at discharge measurement stage (to verify n) (Q-3):

CROSS SECTIONAL AREA =	243.735	SQ FEET
WETTED PERIMETER =	154.144	FEET
HYDRAULIC RADIUS =	1.581	FEET
GRADIENT =	0.0029	FEET/FOOT
MANNINGS N =	0.047	
MAXIMUM DEPTH =	2.400	FEET
MEAN DEPTH =	1.583	FEET
TOP WIDTH =	153.997	FEET
MEAN VELOCITY =	2.323	FEET/SEC
DISCHARGE =	566.259	CUBIC FEET/SEC

#	DISTANCE	DEPTH OF WATER
1	16.002	0.
2	25.000	0.500
3	30.000	0.950
4	35.000	1.000
5	40.000	1.300
6	45.000	1.600
7	50.000	1.800
8	55.000	2.000
9	60.000	2.200
10	65.000	2.200
11	70.000	2.300
12	75.000	2.400
13	80.000	2.400
14	85.000	2.300
15	90.000	2.200
16	95.000	2.100
17	100.000	2.100
18	105.000	1.900
19	110.000	1.800
20	115.000	1.800
21	120.000	1.700
22	125.000	1.600
23	130.000	1.700
24	135.000	1.600
25	140.000	1.500
26	145.000	1.500
27	150.000	1.400
28	155.000	1.100
29	160.000	0.900
30	165.000	0.700
31	169.999	0.



CHANNEL CROSS SECTION, BEAVER CREEK - Q3



INDIRECT RATING CURVE, BEAVER CREEK, Q 3

Beaver Creek, CHANL Program: selected output
Q-4

Cross Section Data:

ABOVE ENTRY LOW PT	TAPE DIST	FORESIGHT OR VERTICAL DIST	CORRECTED HORIZONTAL DIST	ELEV. X-SECT
1	0.	8.800	0.	4.750
2	5.000	9.100	5.000	4.450
3	6.000	10.000	6.000	3.550
4	7.000	11.000	7.000	2.550
5	10.000	10.750	10.000	2.800
6	15.000	10.800	15.000	2.750
7	20.000	10.900	20.000	2.650
8	25.000	11.800	25.000	1.750
9	30.000	12.200	30.000	1.350
10	35.000	12.800	35.000	0.750
11	40.000	12.800	40.000	0.750
12	45.000	11.700	45.000	1.850
13	50.000	11.800	50.000	1.750
14	55.000	11.600	55.000	1.950
15	60.000	11.600	60.000	1.950
16	65.000	11.700	65.000	1.850
17	70.000	11.750	70.000	1.800
18	75.000	11.800	75.000	1.750
19	80.000	12.450	80.000	1.100
20	85.000	12.000	85.000	1.550
21	90.000	11.800	90.000	1.750
22	95.000	11.700	95.000	1.850
23	100.000	11.550	100.000	2.000
24	105.000	11.500	105.000	2.050
25	110.000	11.600	110.000	1.950
26	115.000	11.750	115.000	1.800
27	120.000	12.200	120.000	1.350
28	125.000	13.400	125.000	0.150
29	130.000	13.550	130.000	0.
30	136.000	12.500	136.000	1.050
31	136.100	10.000	136.100	3.550
32	138.000	8.600	138.000	4.950

Rating Table, Q-4, (s=.0022, n=.0384):

STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.011	0.000	0.039	0.000	0.039
0.340	1.154	0.666	1.732	7.791	0.222	7.737
0.679	5.166	1.049	4.925	11.212	0.439	11.088
1.019	12.278	1.110	11.063	23.139	0.478	8.460
1.358	26.307	1.283	20.497	34.471	0.595	17.710
1.697	47.833	1.374	34.820	52.882	0.658	31.913
2.036	76.386	1.227	62.264	112.052	0.556	80.219
2.376	166.198	1.649	100.777	116.364	0.866	114.528
2.715	276.682	1.973	140.218	123.706	1.133	121.443
3.054	415.105	2.259	183.739	132.317	1.389	129.584
3.393	591.313	2.596	227.755	133.136	1.711	129.937
3.732	790.707	2.908	271.915	134.095	2.028	130.550
4.072	1012.123	3.199	316.342	135.174	2.340	131.387
4.411	1254.934	3.476	361.052	136.252	2.650	132.224
4.750	1489.826	3.663	406.747	141.892	2.867	137.728

Hydraulic Geometry at discharge measurement stage (to verify n value) (Q-4):

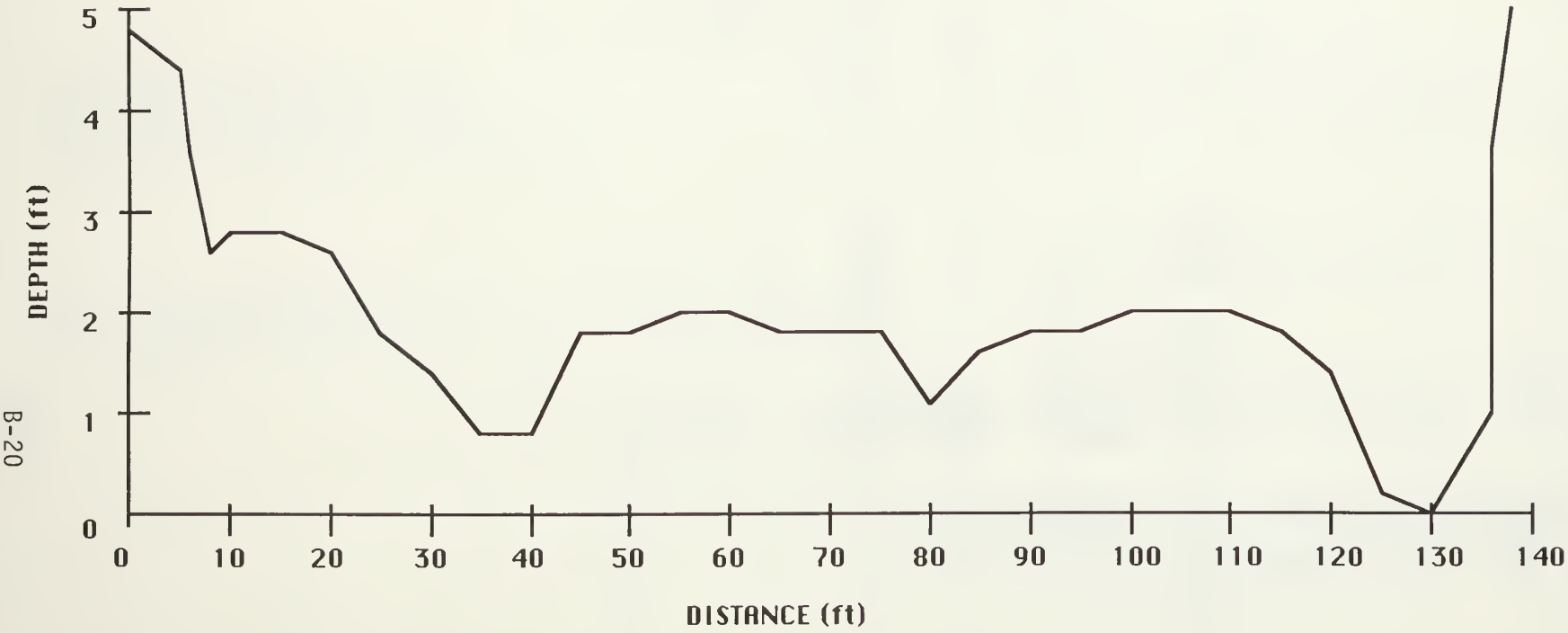
CROSS SECTIONAL AREA =	248.150	SQ FEET
WETTED PERIMETER =	133.515	FEET
HYDRAULIC RADIUS =	1.859	FEET
GRADIENT =	0.0022	FEET/FOOT
MANNINGS N =	0.038	
MAXIMUM DEPTH =	3.550	FEET
MEAN DEPTH =	1.907	FEET
TOP WIDTH =	130.100	FEET
MEAN VELOCITY =	2.744	FEET/SEC
DISCHARGE =	680.879	CUBIC FEET/SEC

#	DISTANCE	DEPTH OF WATER
1	6.000	0.
2	7.000	1.000
3	10.000	0.750
4	15.000	0.800
5	20.000	0.900
6	25.000	1.800
7	30.000	2.200
8	35.000	2.800
9	40.000	2.800
10	45.000	1.700
11	50.000	1.800
12	55.000	1.600
13	60.000	1.600
14	65.000	1.700
15	70.000	1.750
16	75.000	1.800
17	80.000	2.450

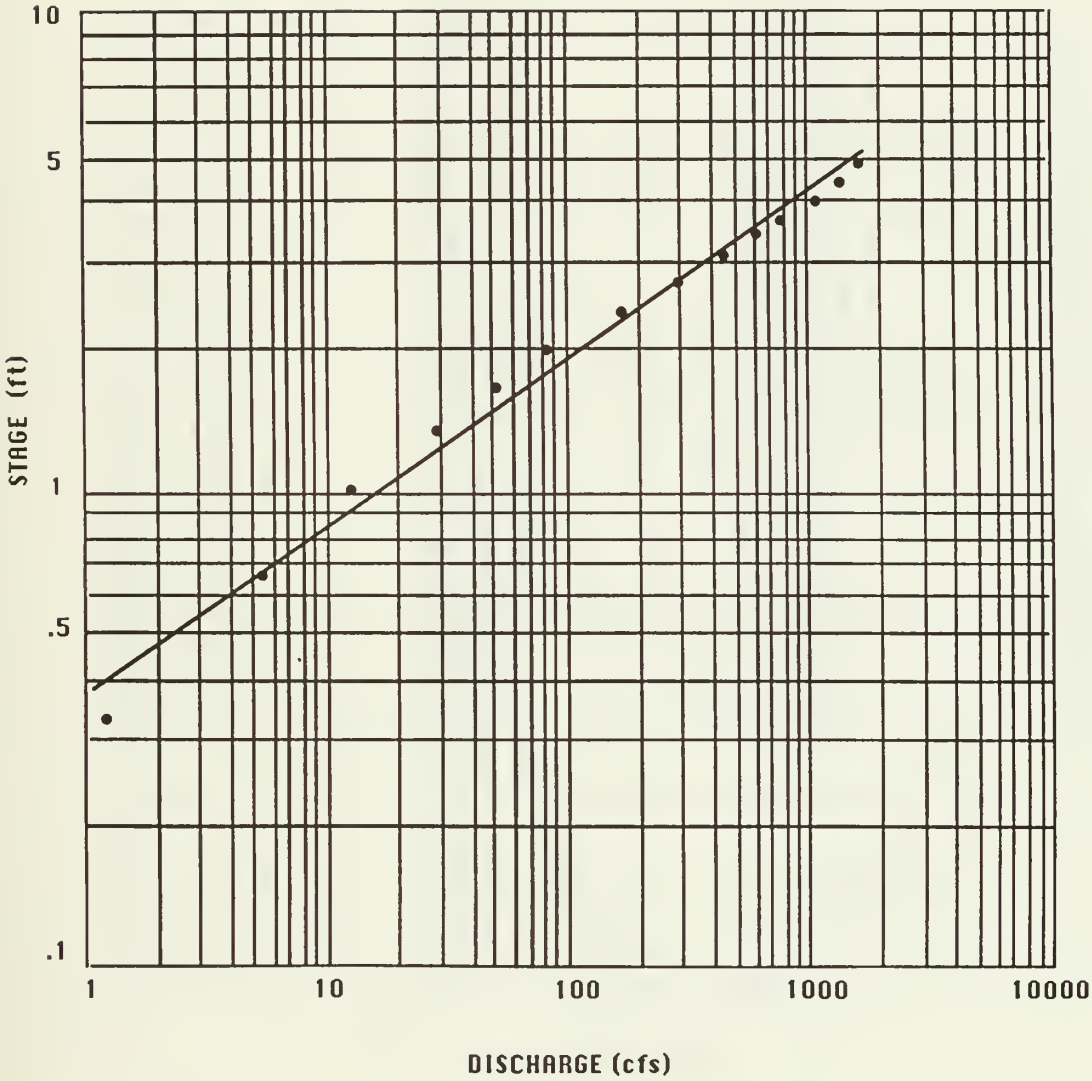
18	85.000	2.000
19	90.000	1.800
20	95.000	1.700
21	100.000	1.550
22	105.000	1.500
23	110.000	1.600
24	115.000	1.750
25	120.000	2.200
26	125.000	3.400
27	130.000	3.550
28	136.000	2.500
29	136.100	0.

Hydraulic Geometry at Bankfull Discharge (Q-4):

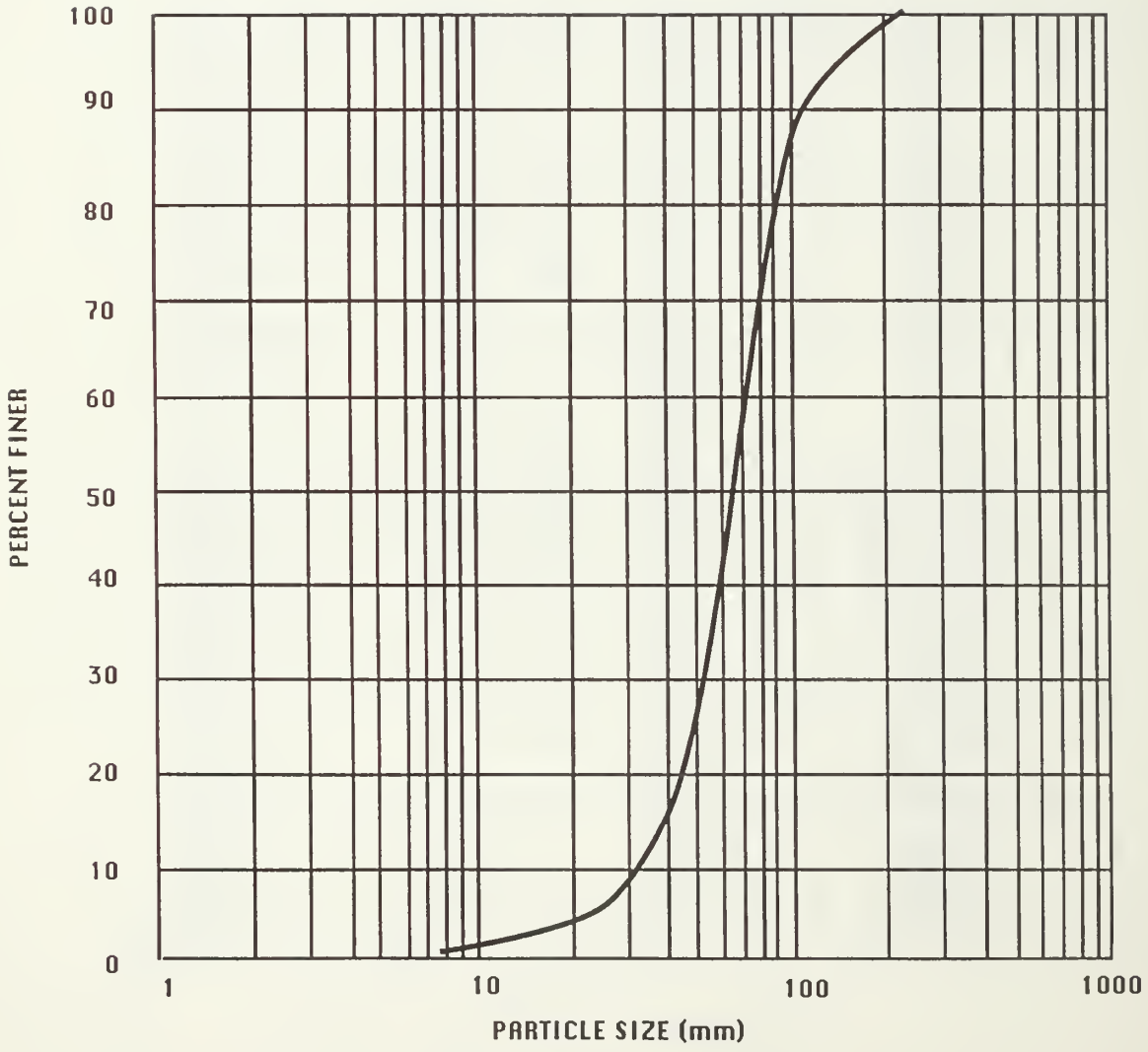
CROSS SECTIONAL AREA =	406.747	SQ FEET
WETTED PERIMETER =	141.892	FEET
HYDRAULIC RADIUS =	2.867	FEET
GRADIENT =	0.0022	FEET/FOOT
MANNINGS N =	0.038	
MAXIMUM DEPTH =	4.750	FEET
MEAN DEPTH =	2.953	FEET
TOP WIDTH =	137.728	FEET
MEAN VELOCITY =	3.663	FEET/SEC
DISCHARGE =	1489.825	CUBIC FEET/SEC



CHANNEL CROSS SECTION, BEAVER CREEK - Q4



INDIRECT RATING CURVE - BEAVER CREEK, Q 4



PARTICLE SIZE DISTRIBUTION - BEAVER CREEK, Q 4

Beaver Creek, CHANL Program: selected output
Q-5

Cross Section Data:

ENTRY LOW PT	DIST	DIST	DIST	X-SECT
1	0.	3.400	0.	11.300
2	2.000	3.400	2.000	11.300
3	9.000	8.000	8.999	6.700
4	15.000	10.000	14.999	4.700
5	25.000	11.100	24.998	3.600
6	35.000	10.400	34.997	4.300
7	45.000	12.100	44.996	2.600
8	55.000	11.000	54.996	3.700
9	65.000	10.950	64.995	3.750
10	75.000	11.150	74.994	3.550
11	85.000	11.400	84.993	3.300
12	95.000	11.700	94.992	3.000
13	105.000	12.300	104.991	2.400
14	115.000	12.750	114.991	1.950
15	125.000	13.400	124.990	1.300
16	135.000	13.900	134.989	0.800
17	145.000	14.400	144.988	0.300
18	155.000	14.500	154.987	0.200
19	165.000	14.600	164.987	0.100
20	175.000	14.600	174.986	0.100
21	185.000	14.700	184.985	0.
22	195.000	14.200	194.984	0.500
23	205.000	14.000	204.983	0.700
24	215.000	13.600	214.982	1.100
25	225.000	14.000	224.982	0.700
26	232.000	10.000	231.981	4.700
27	235.000	6.400	234.981	8.300

Rating Table, Q-5, (s=.0016, n=.0435):

STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.010	0.000	0.040	0.006	1.200	0.005	1.200
0.595	16.277	0.713	22.844	60.667	0.377	60.645
1.180	76.730	1.091	70.340	98.613	0.713	98.432
1.765	202.268	1.542	131.145	109.364	1.199	109.009
2.350	374.288	1.887	198.394	122.292	1.622	121.766
2.935	589.001	2.151	273.774	138.577	1.976	5.016
3.520	825.644	2.277	362.534	168.487	2.152	13.774
4.105	1124.710	2.370	474.649	207.853	2.284	206.600
4.690	1605.303	2.679	599.282	218.338	2.745	216.874
5.275	2196.426	3.022	726.849	221.016	3.289	219.186
5.860	2860.680	3.343	855.729	223.627	3.827	221.429
6.445	3594.328	3.646	985.921	226.238	4.358	223.671
7.030	4399.773	3.938	1117.344	228.407	4.892	225.425
7.615	5273.632	4.220	1249.621	230.234	5.428	226.803
8.200	6209.739	4.491	1382.703	232.060	5.958	228.181

Hydraulic geometry at measured water stage (verifies that n value is correct) (Q-5):

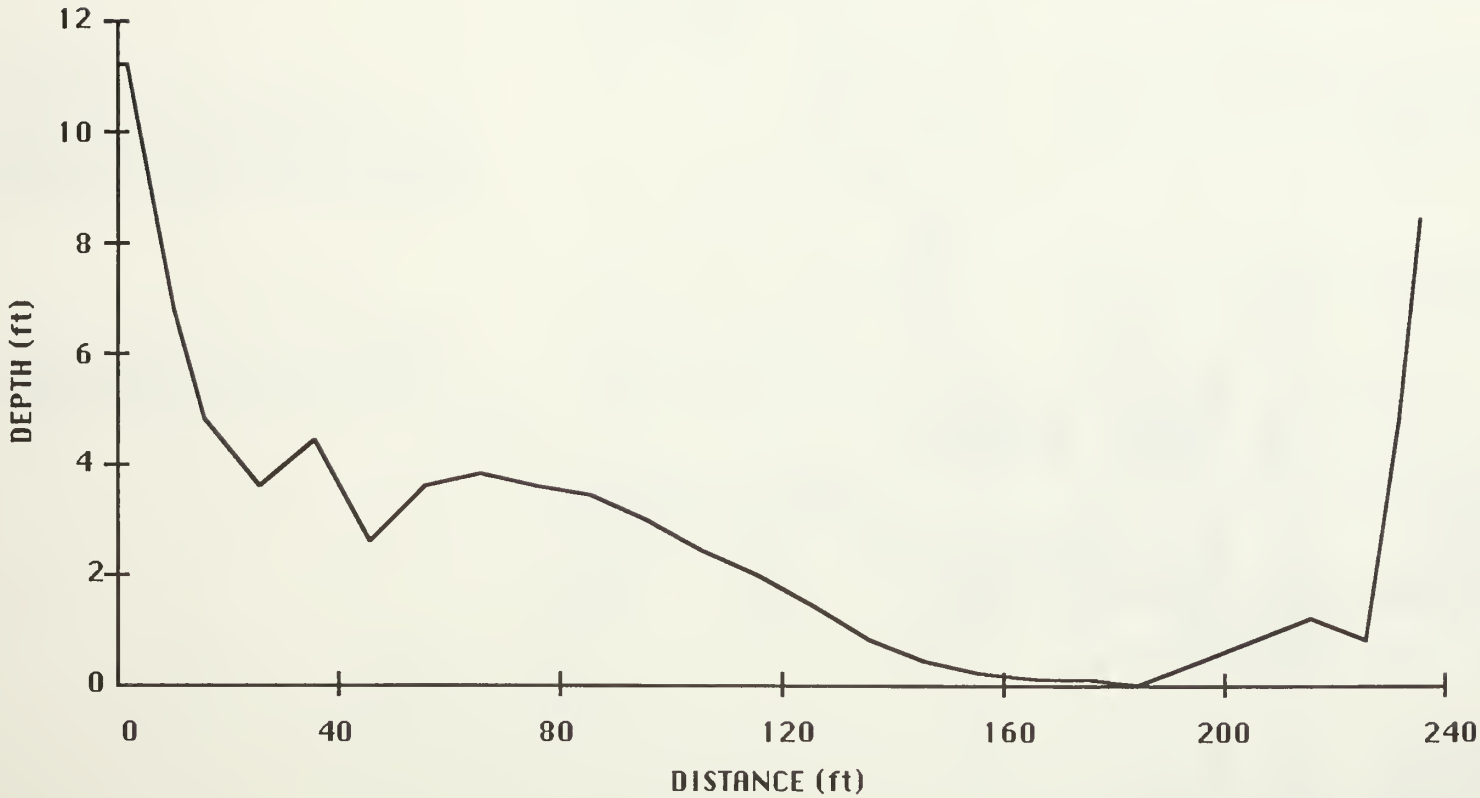
CROSS SECTIONAL AREA =	601.451	SQ FEET
WETTED PERIMETER =	218.449	FEET
HYDRAULIC RADIUS =	2.753	FEET
GRADIENT =	0.0016	FEET/FOOT
MANNINGS N =	0.044	
MAXIMUM DEPTH =	4.700	FEET
MEAN DEPTH =	2.772	FEET
TOP WIDTH =	216.982	FEET
MEAN VELOCITY =	2.684	FEET/SEC
DISCHARGE =	1614.450	CUBIC FEET/SEC

		WATER
1	14.999	0.
2	14.999	0.000
3	24.998	1.100
4	34.997	0.400
5	44.996	2.100
6	54.996	1.000
7	64.995	0.950
8	74.994	1.150
9	84.993	1.400
10	94.992	1.700
11	104.991	2.300
12	114.991	2.750
13	124.990	3.400
14	134.989	3.900
15	144.988	4.400

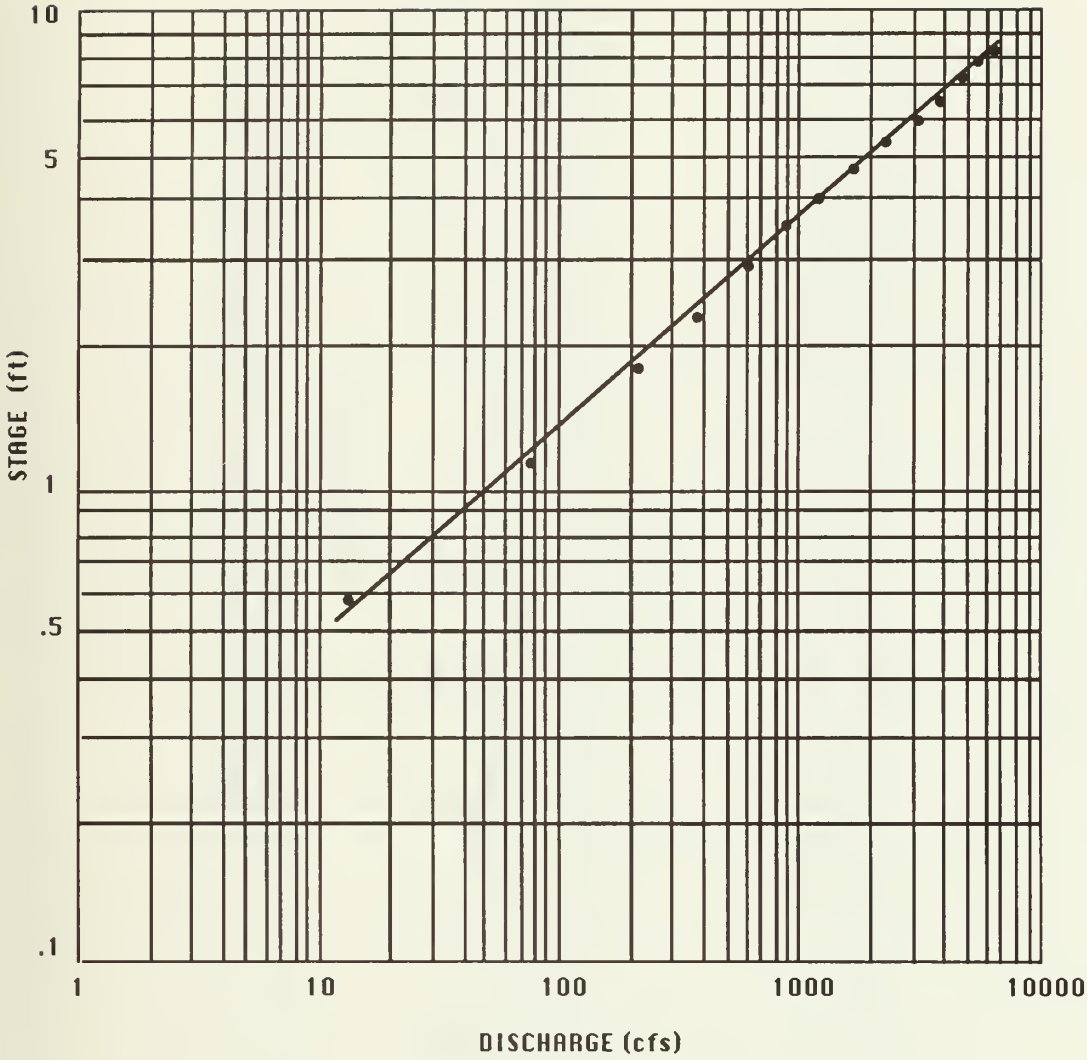
16	154.987	4.500
17	164.987	4.600
18	174.986	4.600
19	184.985	4.700
20	194.984	4.200
21	204.983	4.000
22	214.982	3.600
23	224.982	4.000
24	231.981	0.000
25	231.981	0.

Hydraulic Geometry at Bankfull Stage (Q-5):

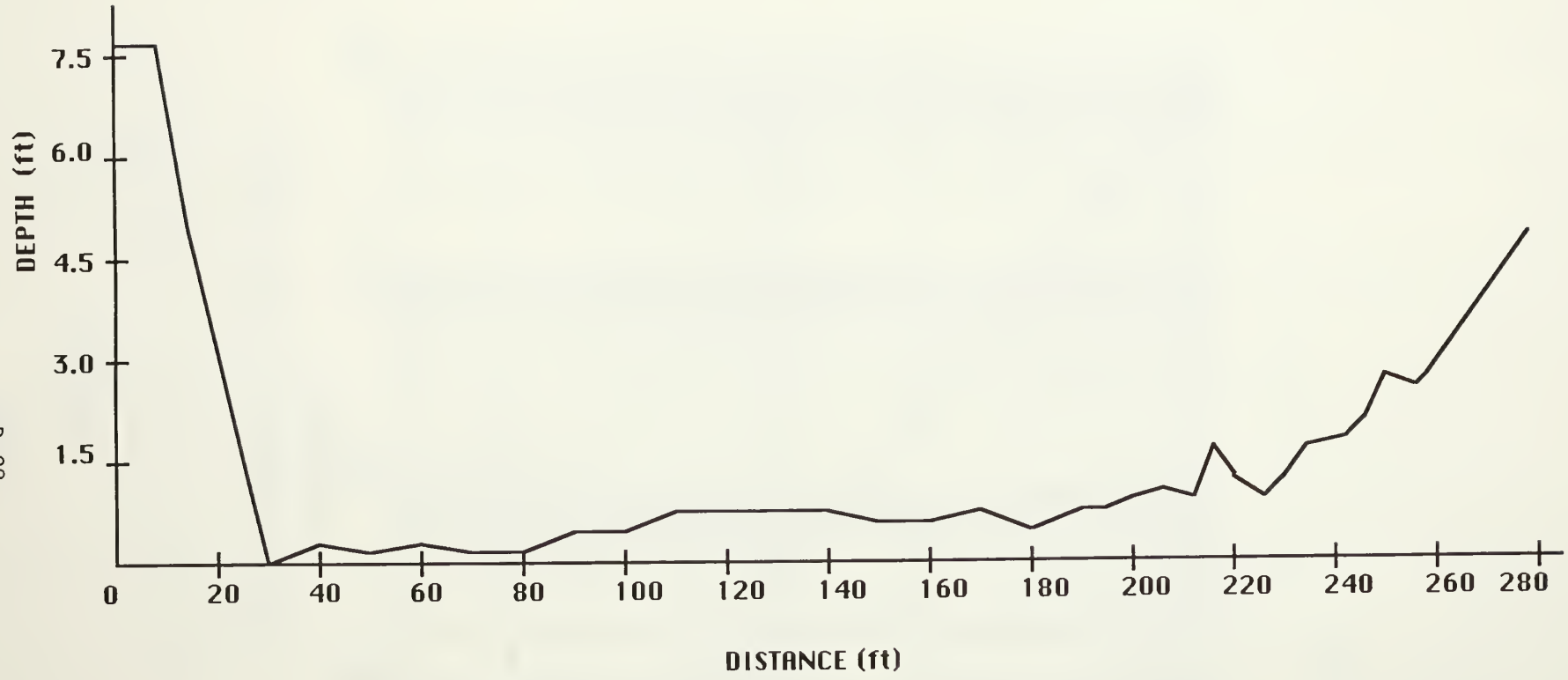
CROSS SECTIONAL AREA =	975.860	SQ FEET
WETTED PERIMETER =	226.037	FEET
HYDRAULIC RADIUS =	4.317	FEET
GRADIENT =	0.0016	FEET/FOOT
MANNINGS N =	0.044	
MAXIMUM DEPTH =	6.400	FEET
MEAN DEPTH =	4.366	FEET
TOP WIDTH =	223.498	FEET
MEAN VELOCITY =	3.623	FEET/SEC
DISCHARGE =	3535.496	CUBIC FEET/SEC



CHANNEL CROSS SECTION, BEAVER CREEK - Q 5



INDIRECT RATING CURVE, BEAVER CREEK, Q 5



CHANNEL CROSS SECTION, BEAVER CREEK - Q 6

Beaver Creek, CHANL Program: selected output
Q-6

Cross Section Data:

ABOVE ENTRY LOW PT	TAPE DIST	FORESIGHT OR VERTICAL DIST	CORRECTED HORIZONTAL DIST	ELEV. X-SECT
1	0.	5.100	0.	7.600
2	7.000	5.100	7.000	7.600
3	14.200	7.600	14.199	5.100
4	22.000	10.000	21.999	2.700
5	30.000	12.700	29.998	0.
6	40.000	12.400	39.998	0.300
7	50.000	12.600	49.997	0.100
8	60.000	12.500	59.997	0.200
9	70.000	12.550	69.997	0.150
10	80.000	12.600	79.996	0.100
11	90.000	12.300	89.995	0.400
12	100.000	12.300	99.995	0.400
13	110.000	12.000	109.995	0.700
14	120.000	12.000	119.994	0.700
15	130.000	11.950	129.993	0.750
16	140.000	12.000	139.993	0.700
17	150.000	12.100	149.993	0.600
18	160.000	12.050	159.992	0.650
19	170.000	12.000	169.991	0.700
20	180.000	12.200	179.991	0.500
21	190.000	12.000	189.990	0.700
22	195.000	12.000	194.990	0.700
23	200.000	11.850	199.990	0.850
24	205.000	11.600	204.990	1.100
25	210.000	11.900	209.990	0.800
26	215.000	11.000	214.989	1.700
27	220.000	11.600	219.989	1.100
28	225.000	11.900	224.989	0.800
29	230.000	11.450	229.989	1.250
30	235.000	11.000	234.988	1.700
31	240.000	10.900	239.988	1.800
32	245.000	10.600	244.988	2.100
33	250.000	10.000	249.987	2.700
34	255.000	10.200	254.987	2.500
35	257.000	10.000	256.987	2.700
36	280.000	7.900	279.986	4.800

Rating Table, Q-6, (s=.0033, n=.0409):

STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.013	0.000	0.036	0.000	0.036
0.344	6.758	0.653	10.354	59.209	0.175	59.142
0.687	36.372	0.945	38.490	126.342	0.305	107.553
1.029	131.913	1.349	97.817	188.337	0.519	181.725
1.372	301.435	1.828	164.914	201.225	0.820	187.235
1.715	528.032	2.243	235.411	211.303	1.114	210.817
2.058	809.539	2.614	309.681	220.932	1.402	220.381
2.401	1153.758	2.989	386.001	225.232	1.714	224.606
2.743	1522.124	3.276	464.662	236.319	1.966	235.603
3.086	1965.923	3.599	546.258	241.254	2.264	240.471
3.429	2456.929	3.903	629.522	246.190	2.557	245.339
3.772	2994.007	4.191	714.456	251.125	2.845	250.207
4.114	3576.285	4.464	801.057	256.060	3.128	255.076
4.457	4203.092	4.726	889.328	260.996	3.407	259.944
4.800	4873.909	4.977	979.267	265.931	3.682	264.812

Channel Geometry at discharge measurement stage (to verify n value) (Q-6):

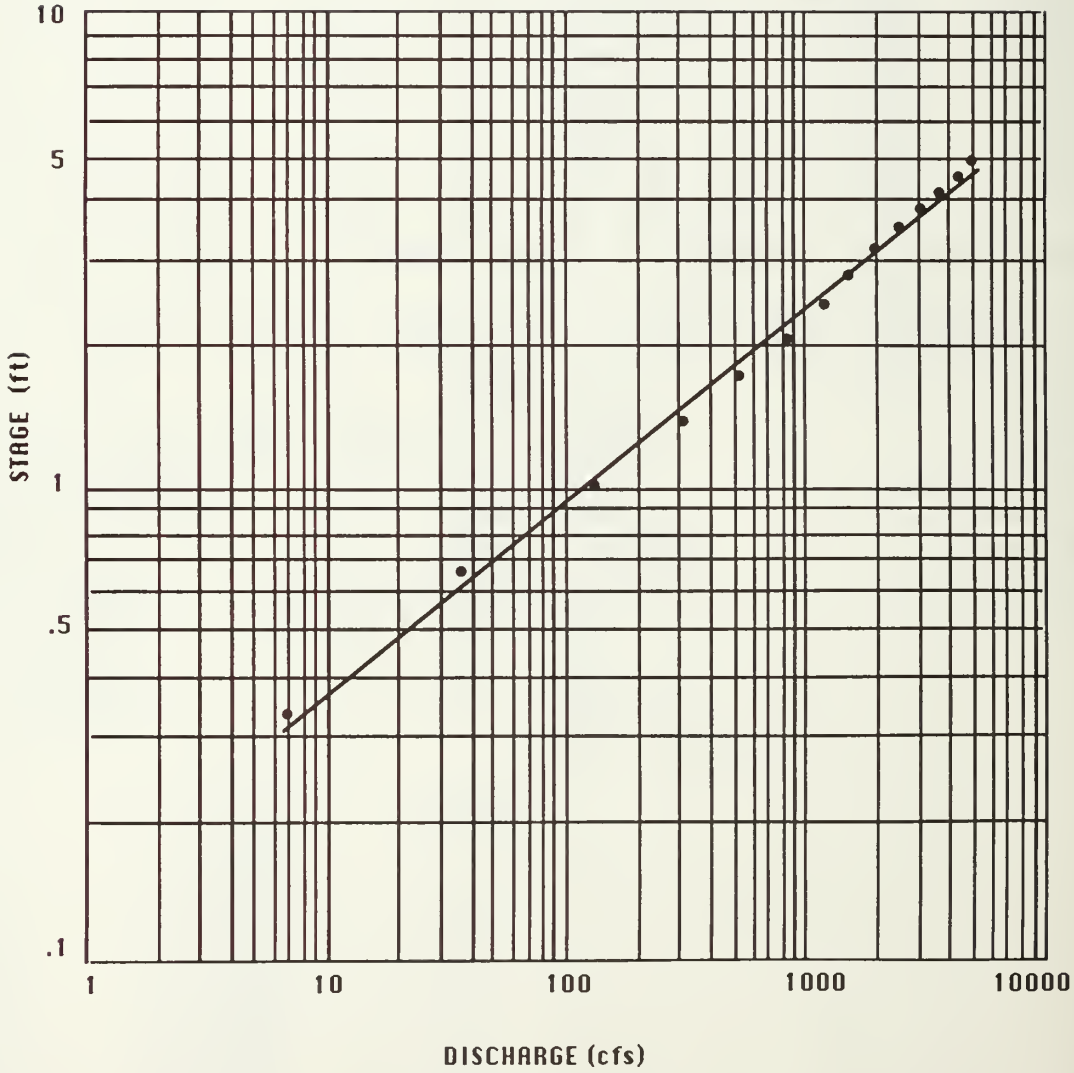
CROSS SECTIONAL AREA =	454.477	SQ FEET
WETTED PERIMETER =	235.696	FEET
HYDRAULIC RADIUS =	1.928	FEET
GRADIENT =	0.0033	FEET/FOOT
MANNINGS N =	0.041	
MAXIMUM DEPTH =	2.700	FEET
MEAN DEPTH =	1.934	FEET
TOP WIDTH =	234.988	FEET
MEAN VELOCITY =	3.233	FEET/SEC
DISCHARGE =	1469.510	CUBIC FEET/SEC

#	DISTANCE	DEPTH OF WATER
1	21.999	0.
2	21.999	0.000
3	29.998	2.700
4	39.998	2.400
5	49.997	2.600
6	59.997	2.500
7	69.997	2.550
8	79.996	2.600
9	89.995	2.300
10	99.995	2.300
11	109.995	2.000
12	119.994	2.000
13	129.993	1.950
14	139.993	2.000
15	149.993	2.100
16	159.992	2.050

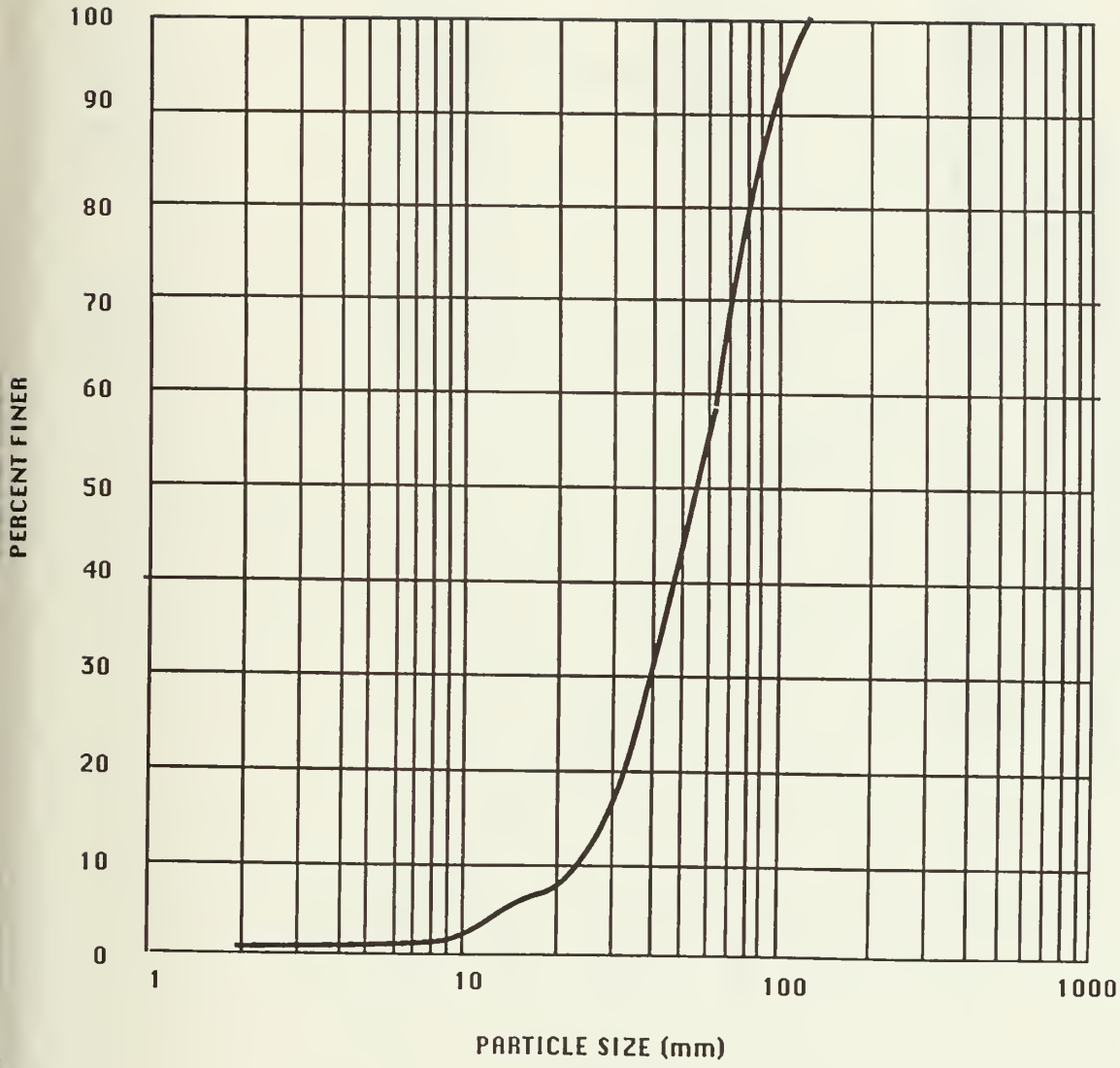
17	169.991	2.000
18	179.991	2.200
19	189.990	2.000
20	194.990	2.000
21	199.990	1.850
22	204.990	1.600
23	209.990	1.900
24	214.989	1.000
25	219.989	1.600
26	224.989	1.900
27	229.989	1.450
28	234.988	1.000
29	239.988	0.900
30	244.988	0.600
31	249.987	0.000
32	254.987	0.200
33	256.987	0.000
34	256.987	0.

Channel Geometry at Bankfull Stage (Q-6):

CROSS SECTIONAL AREA =	979.267	SQ FEET
WETTED PERIMETER =	265.931	FEET
HYDRAULIC RADIUS =	3.682	FEET
GRADIENT =	0.0033	FEET/FOOT
MANNINGS N =	0.041	
MAXIMUM DEPTH =	4.800	FEET
MEAN DEPTH =	3.698	FEET
TOP WIDTH =	264.812	FEET
MEAN VELOCITY =	4.977	FEET/SEC
DISCHARGE =	4873.909	CUBIC FEET/SEC



INDIRECT RATING CURVE - BEAVER CREEK, Q 6

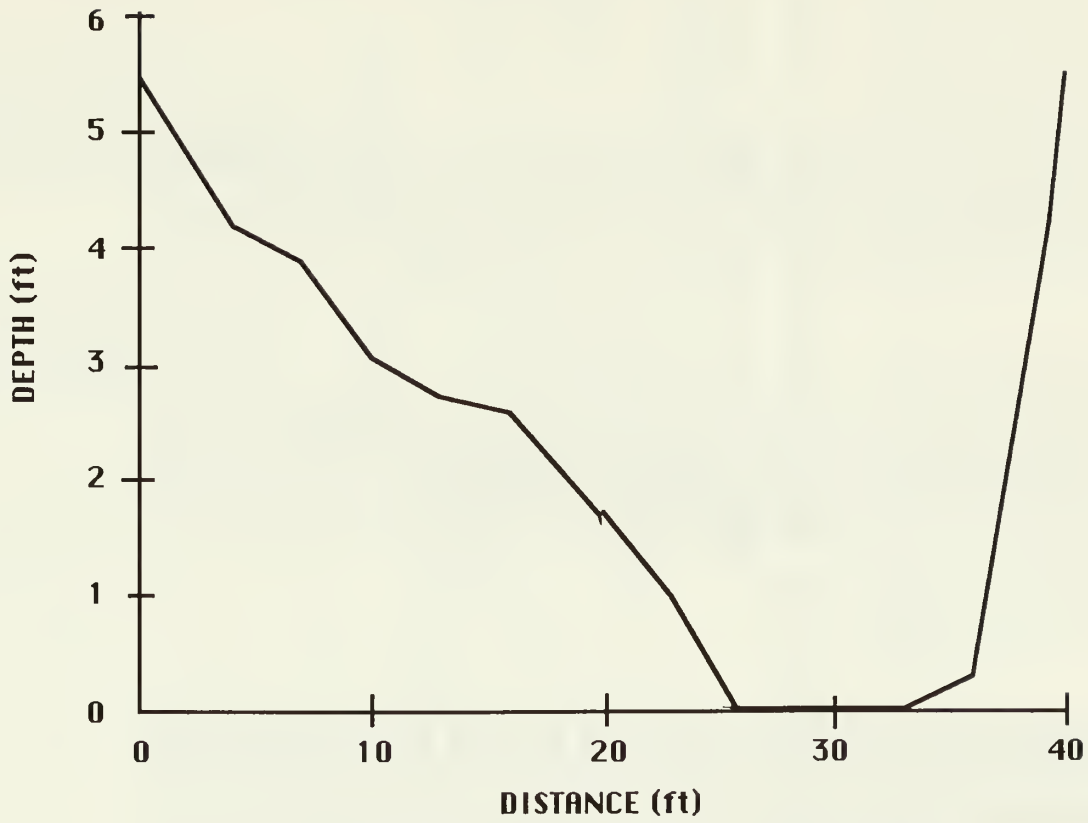


PARTICLE SIZE DISTRIBUTION - BEAVER CREEK, Q 6

Beaver Creek, CHANL Program: selected output
Q-6 slough

Cross Section Data:

ABOVE ENTRY LOW PT	TAPE DIST	OR VERTICAL DIST	HORIZONTAL DIST	ELEV. X-SECT
1	0.	8.700	0.	5.500
2	3.500	10.000	3.500	4.200
3	7.000	10.300	7.000	3.900
4	10.000	11.100	10.000	3.100
5	13.000	11.500	13.000	2.700
6	16.000	11.600	16.000	2.600
7	20.000	12.500	20.000	1.700
8	23.000	13.200	23.000	1.000
9	26.000	14.200	26.000	0.
10	30.000	14.200	30.000	0.
11	33.000	14.200	33.000	0.
12	36.000	13.900	36.000	0.300
13	39.500	10.000	39.500	4.200
14	40.000	8.700	40.000	5.500



CHANNEL CROSS SECTION, BEAVER CREEK
Q 6 - SLOUGH

Beaver Creek, CHANL Program: selected output
Q-7

Cross Section Data:

LOW PT

1	0.	4.550	0.	12.650
2	4.000	9.350	4.000	7.850
3	5.000	10.000	5.000	7.200
4	10.000	13.000	9.999	4.200
5	20.000	16.000	19.998	1.200
6	30.000	17.200	29.997	0.
7	40.000	16.700	39.996	0.500
8	50.000	15.900	49.995	1.300
9	60.000	15.500	59.994	1.700
10	70.000	15.000	69.993	2.200
11	80.000	15.000	79.992	2.200
12	90.000	15.100	89.991	2.100
13	100.000	15.250	99.990	1.950
14	110.000	15.300	109.989	1.900
15	120.000	15.500	119.988	1.700
16	130.000	15.700	129.987	1.500
17	140.000	16.100	139.986	1.100
18	150.000	16.300	149.985	0.900
19	160.000	16.300	159.984	0.900
20	170.000	16.000	169.983	1.200
21	180.000	15.800	179.982	1.400
22	190.000	15.200	189.981	2.000
23	200.000	15.200	199.980	2.000
24	210.000	14.800	209.979	2.400
25	220.000	14.000	219.978	3.200
26	225.000	13.700	224.978	3.500
27	230.000	13.000	229.977	4.200
28	235.000	12.200	234.977	5.000
29	240.000	11.800	239.976	5.400
30	245.000	11.250	244.976	5.950
31	250.000	11.050	249.975	6.150
32	255.000	10.250	254.975	6.950
33	257.000	10.000	256.975	7.200
34	260.000	9.700	259.974	7.500
35	274.000	8.400	273.973	8.800

Rating Table, Q-7 (s=.001, n=.0379):

STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.008	0.000	0.028	0.000	0.028
0.629	3.274	0.590	5.550	16.918	0.328	16.863
1.258	20.517	0.710	28.890	66.645	0.433	29.665
1.886	87.966	0.993	88.616	123.704	0.716	46.014
2.515	245.545	1.245	197.295	196.184	1.006	195.802
3.143	541.421	1.674	323.483	206.252	1.568	205.752
3.772	930.964	2.040	456.255	216.117	2.111	215.495
4.400	1416.810	2.386	593.711	222.352	2.670	221.565
5.029	1988.151	2.707	734.530	227.731	3.225	226.722
5.657	2622.542	2.981	879.710	235.959	3.728	234.747
6.286	3320.615	3.224	1030.097	245.720	4.192	244.303
6.914	4136.964	3.491	1185.205	250.919	4.723	249.278
7.543	5009.061	3.727	1343.858	257.823	5.212	255.965
8.171	5944.896	3.945	1507.126	265.602	5.674	263.473
8.800	6956.755	4.153	1675.011	273.217	6.131	270.765

Channel Geometry at measurement stage (to verify n value)(Q-7):

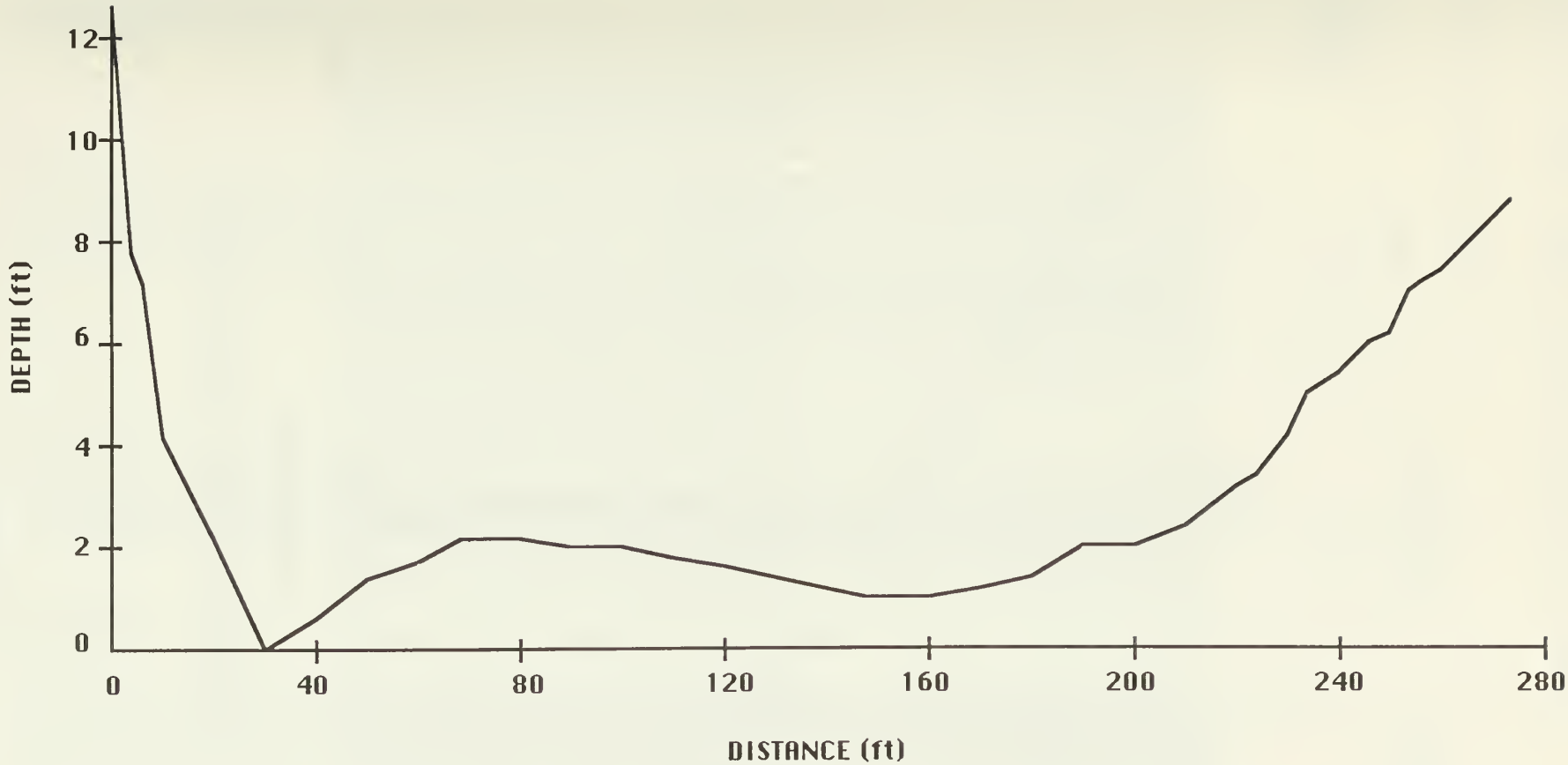
CROSS SECTIONAL AREA =	1256.751	SQ FEET
WETTED PERIMETER =	253.714	FEET
HYDRAULIC RADIUS =	4.953	FEET
GRADIENT =	0.0010	FEET/FOOT
MANNINGS N =	0.038	
MAXIMUM DEPTH =	7.200	FEET
MEAN DEPTH =	4.988	FEET
TOP WIDTH =	251.975	FEET
MEAN VELOCITY =	3.603	FEET/SEC
DISCHARGE =	4527.943	CUBIC FEET/SEC

#	DISTANCE	DEPTH OF WATER
1	5.000	0.
2	5.000	0.000
3	9.999	3.000
4	19.998	6.000
5	29.997	7.200
6	39.996	6.700
7	49.995	5.900
8	59.994	5.500
9	69.993	5.000
10	79.992	5.000
11	89.991	5.100
12	99.990	5.250
13	109.989	5.300
14	119.988	5.500
15	129.987	5.700
16	139.986	6.100
17	149.985	6.300
18	159.984	6.300

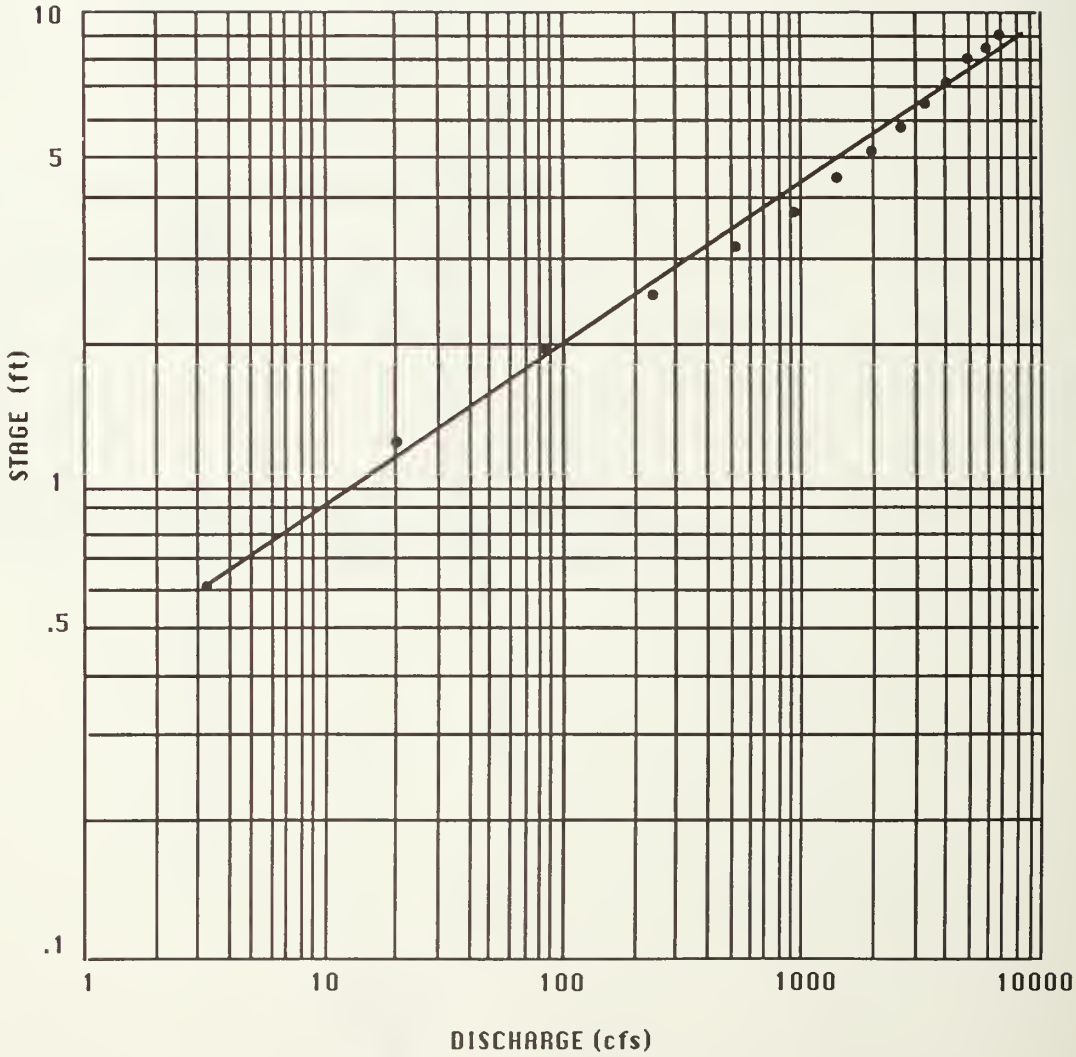
19	169.983	6.000
20	179.982	5.800
21	189.981	5.200
22	199.980	5.200
23	209.979	4.800
24	219.978	4.000
25	224.978	3.700
26	229.977	3.000
27	234.977	2.200
28	239.976	1.800
29	244.976	1.250
30	249.975	1.050
31	254.975	0.250
32	256.975	0.000
33	256.975	0.

Channel Geometry at Bankfull Stage: Q7

CROSS SECTIONAL AREA =	1384.196	SQ FEET
WETTED PERIMETER =	259.809	FEET
HYDRAULIC RADIUS =	5.328	FEET
GRADIENT =	0.0010	FEET/FOOT
MANNINGS N =	0.038	
MAXIMUM DEPTH =	7.700	FEET
MEAN DEPTH =	5.367	FEET
TOP WIDTH =	257.898	FEET
MEAN VELOCITY =	3.782	FEET/SEC
DISCHARGE =	5235.304	CUBIC FEET/SEC



CHANNEL CROSS SECTION, BEAVER CREEK - Q 7



INDIRECT RATING CURVE - BEAVER CREEK, Q 7

Beaver Creek, CHANL Program: selected output
Geom-1

Cross Section Data:

ABOVE ENTRY LOW PT	TAPE DIST	FORESIGHT OR VERTICAL DIST	CORRECTED HORIZONTAL DIST	ELEV. X-SECT
1	0.	6.800	0.	5.900
2	5.000	6.800	5.000	5.900
3	10.000	6.600	9.999	6.100
4	20.000	7.500	19.999	5.200
5	30.000	7.500	29.998	5.200
6	40.000	7.100	39.998	5.600
7	50.000	7.200	49.997	5.500
8	60.000	6.700	59.997	6.000
9	69.000	6.800	68.996	5.900
10	78.000	10.000	77.996	2.700
11	80.000	10.400	79.995	2.300
12	82.000	10.400	81.995	2.300
13	84.000	10.800	83.995	1.900
14	86.000	11.000	85.995	1.700
15	88.000	11.000	87.995	1.700
16	90.000	10.900	89.995	1.800
17	92.000	11.000	91.995	1.700
18	94.000	11.100	93.995	1.600
19	96.000	11.100	95.995	1.600
20	98.000	11.100	97.994	1.600
21	100.000	11.100	99.994	1.600
22	102.000	11.100	101.994	1.600
23	104.000	11.100	103.994	1.600
24	106.000	11.300	105.994	1.400
25	108.000	11.200	107.994	1.500
26	110.000	10.900	109.994	1.800
27	112.000	11.000	111.994	1.700
28	114.000	10.800	113.994	1.900
29	116.000	11.100	115.993	1.600
30	118.000	11.100	117.993	1.600
31	120.000	11.000	119.993	1.700
32	122.000	10.900	121.993	1.800
33	124.000	11.000	123.993	1.700
34	126.000	11.100	125.993	1.600
35	128.000	10.800	127.993	1.900
36	130.000	11.000	129.993	1.700
37	132.000	10.600	131.992	2.100
38	134.000	10.500	133.992	2.200
39	136.000	10.500	135.992	2.200
40	138.000	10.700	137.992	2.000
41	140.000	10.700	139.992	2.000
42	142.000	10.800	141.992	1.900
43	144.000	10.900	143.992	1.800

Cross Section Data, Geom-1 (continued):

44	146.000	10.800	145.992	1.900
45	148.000	10.800	147.992	1.900
46	150.000	10.800	149.991	1.900
47	152.000	10.500	151.991	2.200
48	154.000	10.700	153.991	2.000
49	156.000	10.500	155.991	2.200
50	156.000	10.500	155.991	2.200
51	158.000	11.300	157.991	1.400
52	160.000	11.800	159.991	0.900
53	162.000	12.200	161.991	0.500
54	164.000	12.700	163.991	0.
55	166.000	12.600	165.991	0.100
56	168.000	12.400	167.990	0.300
57	170.000	11.700	169.990	1.000
58	172.000	10.800	171.990	1.900
59	173.000	10.000	172.990	2.700
60	174.000	9.300	173.990	3.400
61	176.000	8.300	175.990	4.400
62	178.000	4.900	177.990	7.800

Rating Table, Geom-1 (n=.041)

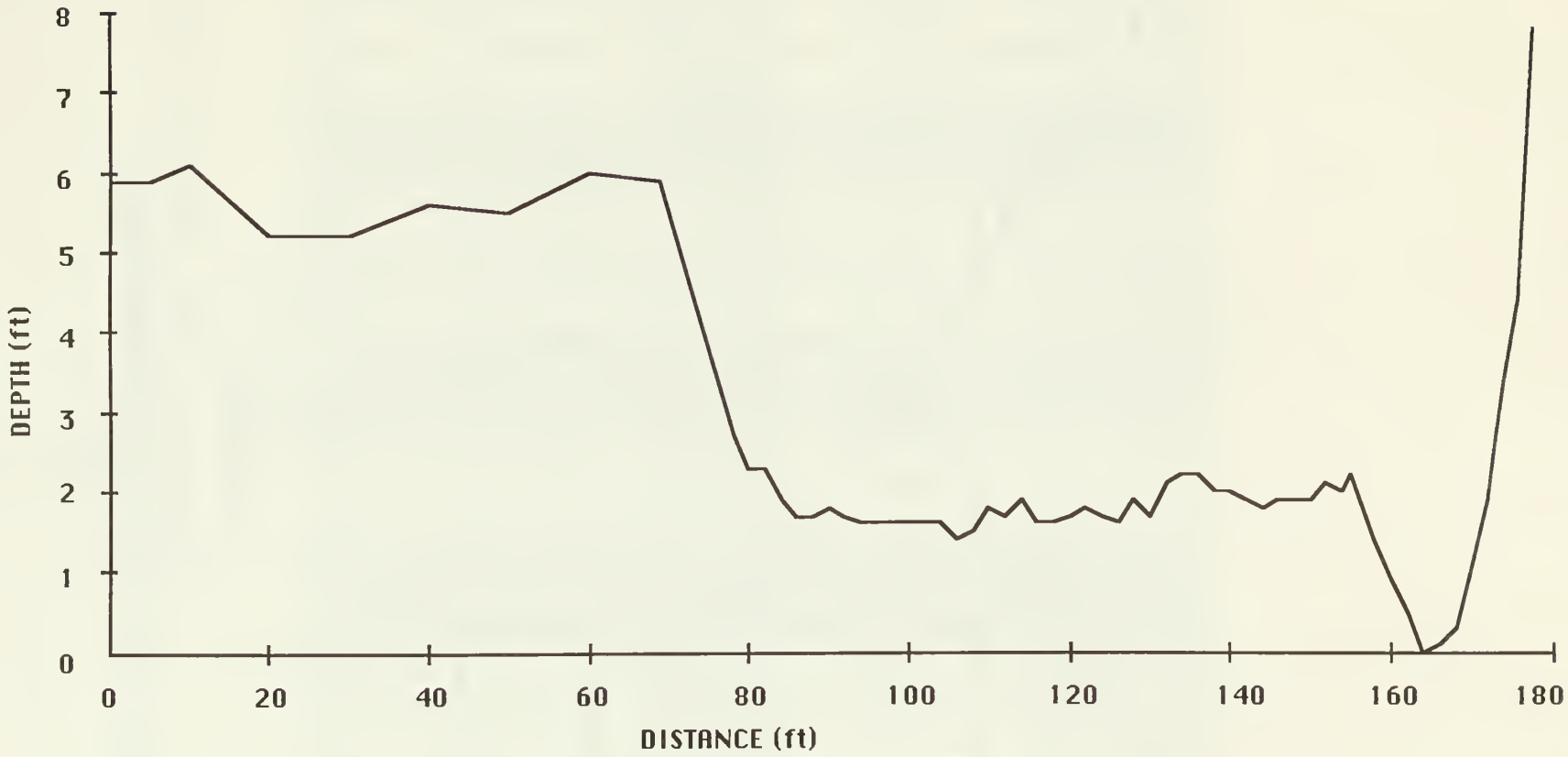
STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.012	0.000	0.024	0.000	0.024
0.422	1.254	0.800	1.567	6.123	0.256	6.038
0.844	6.012	1.258	4.778	9.471	0.505	9.270
1.265	15.234	1.639	9.292	12.382	0.750	12.047
1.686	19.863	1.160	17.124	38.338	0.447	23.557
2.107	58.258	1.311	44.424	82.740	0.537	81.815
2.529	149.337	1.808	82.615	95.080	0.869	93.924
2.950	284.005	2.315	122.676	97.409	1.259	96.055
3.371	452.354	2.766	163.518	99.402	1.645	97.841
3.793	650.707	3.172	205.158	101.587	2.020	99.852
4.214	877.886	3.545	247.651	103.786	2.386	101.880
4.635	1134.259	3.898	290.960	105.733	2.752	103.575
5.056	1418.291	4.235	334.896	107.479	3.116	105.008
5.478	1572.554	4.099	383.606	129.271	2.967	126.468
5.899	1766.772	3.976	444.355	156.765	2.835	153.617

Rating Table, Geom-1 (n=.05):

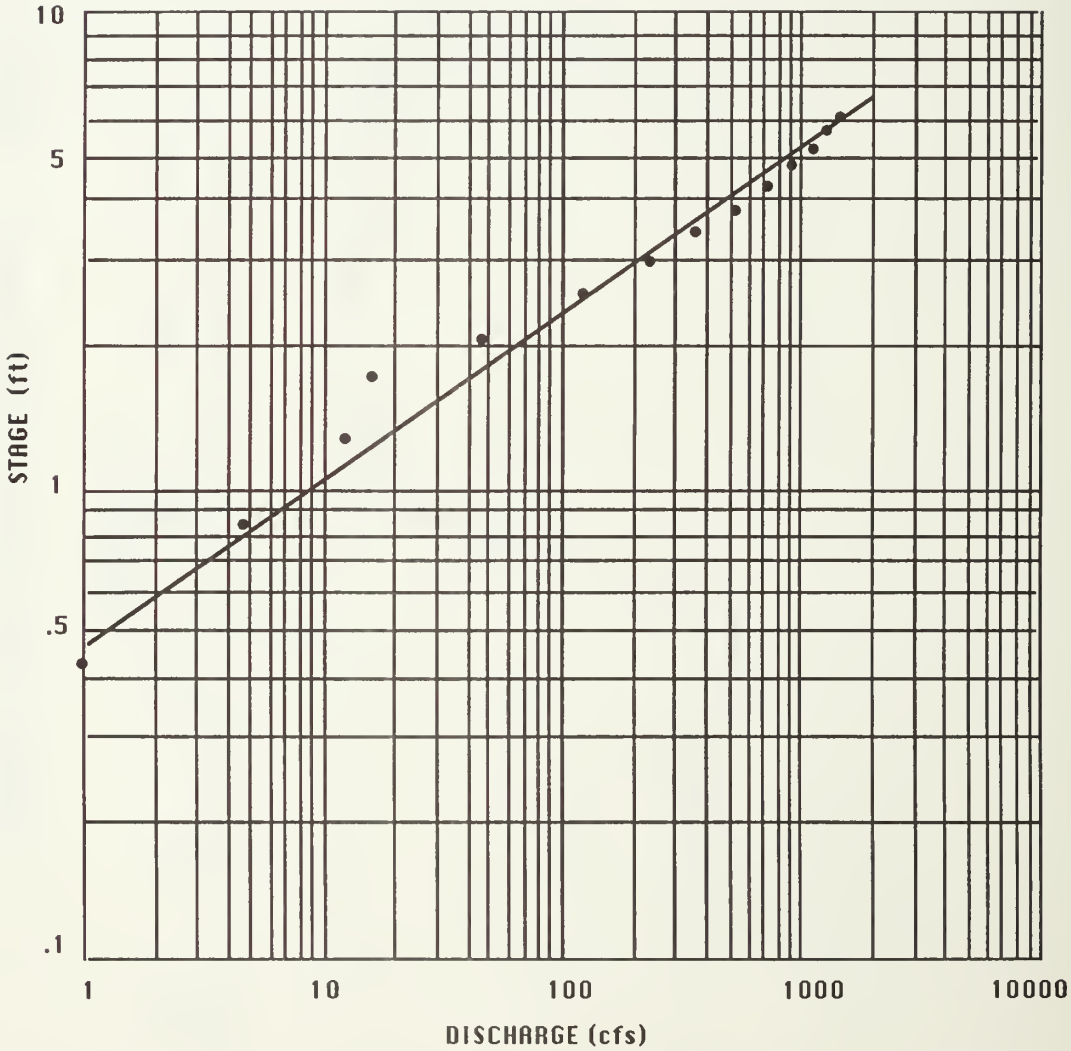
STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.010	0.000	0.024	0.000	0.024
0.422	1.028	0.656	1.567	6.123	0.256	6.038
0.844	4.930	1.032	4.778	9.471	0.505	9.270
1.265	12.492	1.344	9.292	12.382	0.750	12.047
1.686	16.288	0.951	17.124	38.338	0.447	23.557
2.107	47.771	1.075	44.424	82.740	0.537	65.788
2.529	122.456	1.482	82.615	95.080	0.869	93.924
2.950	232.884	1.898	122.676	97.409	1.259	96.055
3.371	370.931	2.268	163.518	99.402	1.645	97.841
3.793	533.580	2.601	205.158	101.587	2.020	99.852
4.214	719.866	2.907	247.651	103.786	2.386	101.880
4.635	930.093	3.197	290.960	105.733	2.752	103.575
5.056	1162.999	3.473	334.896	107.479	3.116	105.008
5.478	1289.494	3.362	383.606	129.271	2.967	20.027
5.899	1448.753	3.260	444.355	156.765	2.835	153.617

Channel Geometry, Bankfull Stage, Geom-1 (n=.041):

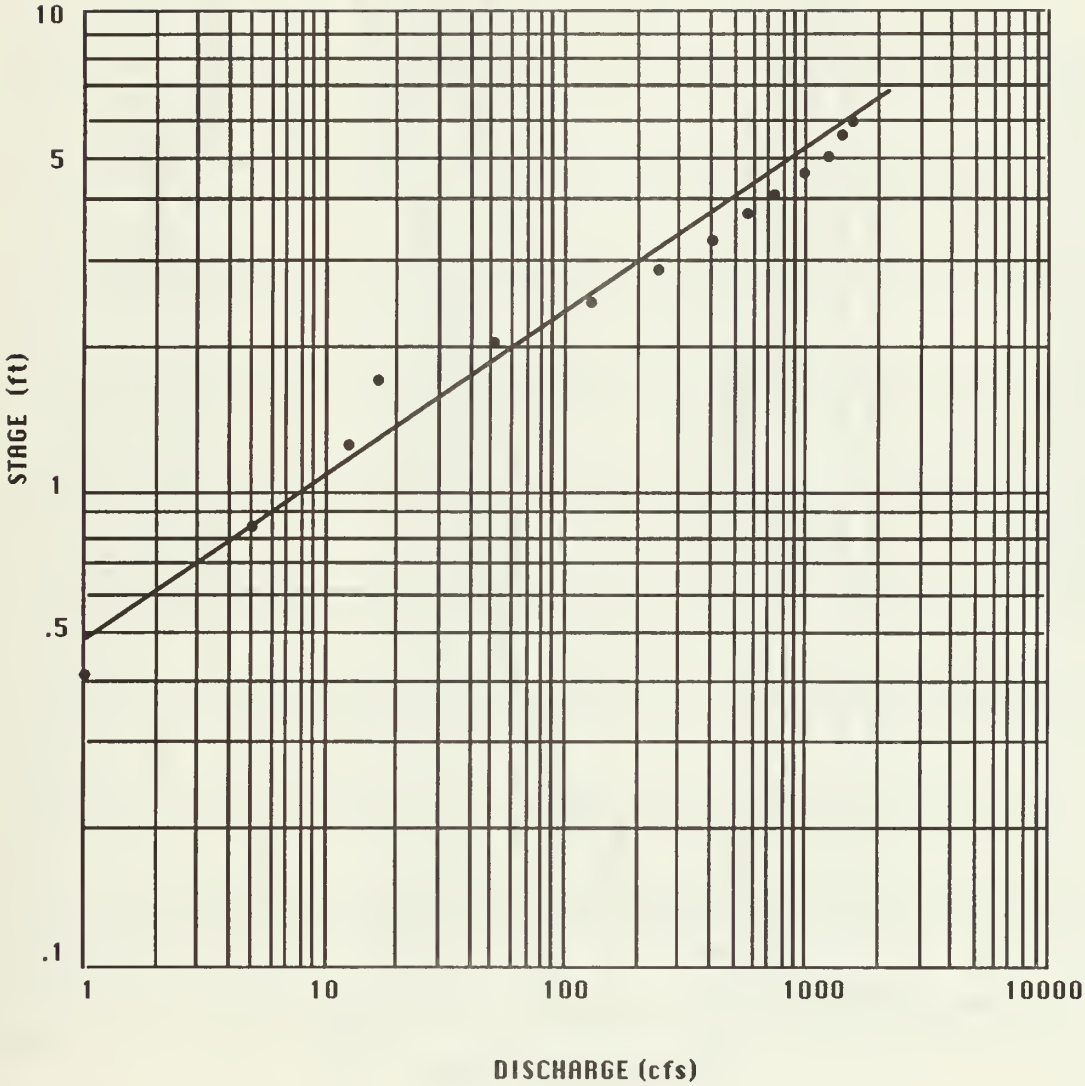
```
*********THERE ARE MULTIPLE CHANNELS AT THIS STAGE.     EQ. MAY

CROSS SECTIONAL AREA = 444.355  SQ FEET
WETTED PERIMETER =     156.765  FEET
HYDRAULIC RADIUS =       2.835  FEET
GRADIENT =               0.0030 FEET/FOOT
MANNINGS N =             0.041
MAXIMUM DEPTH =          5.899  FEET
MEAN DEPTH =             2.893  FEET
TOP WIDTH =            153.617  FEET
MEAN VELOCITY =          3.976  FEET/SEC
DISCHARGE =           1766.772  CUBIC FEET/SEC
```



CHANNEL CROSS SECTION, BEAVER CREEK - GEOM 1

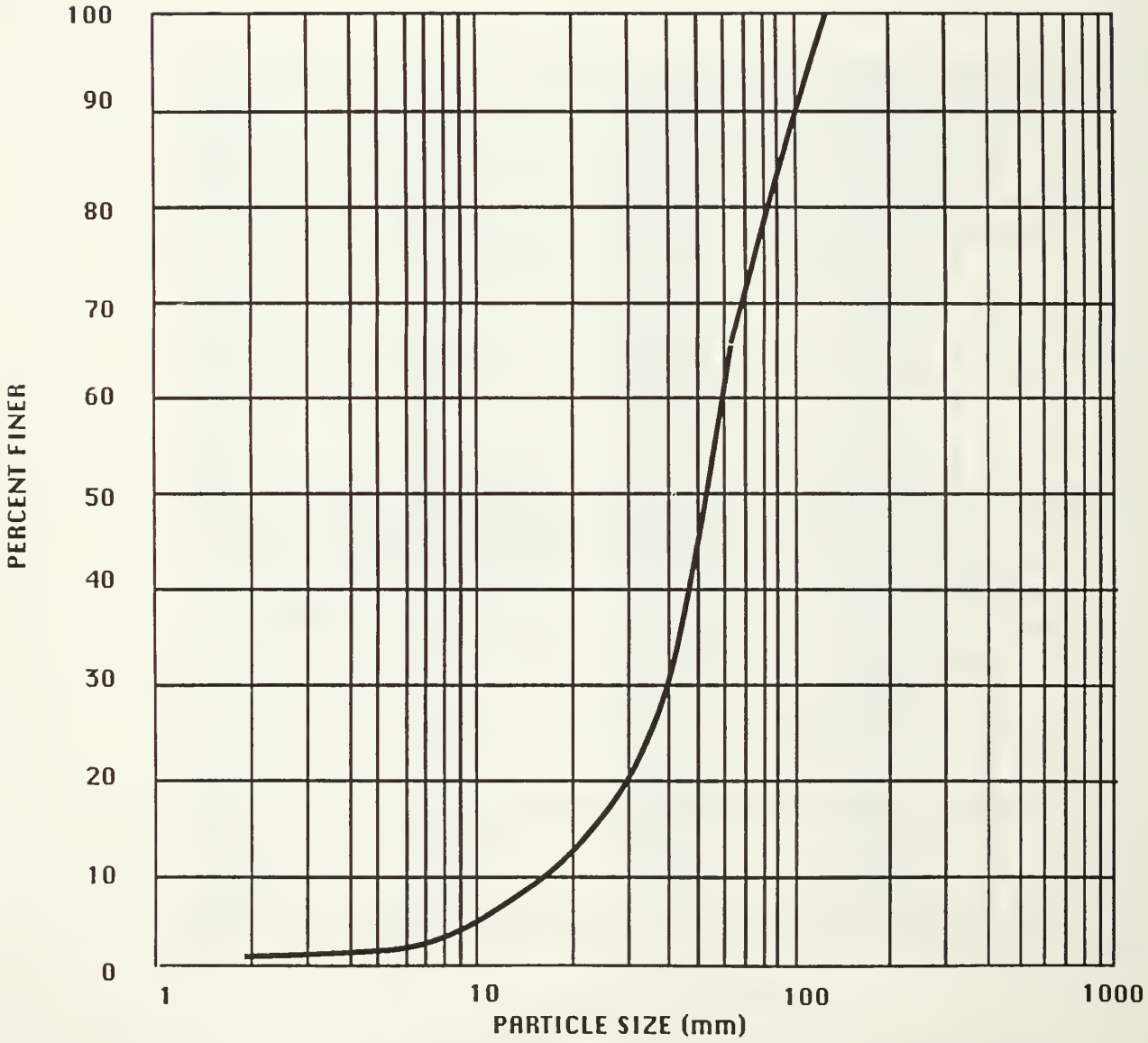


INDIRECT RATING CURVE - BEAVER CREEK, GEOM 1
MANNING'S n = .05



INDIRECT RATING CURVE - BEAVER CREEK, GEOM 1

MANNING'S n = .041



PARTICLE SIZE DISTRIBUTION - BEAVER CREEK, GEOM 1

Beaver Creek, CHANL Program: selected output
Geom-2

Cross Section Data:

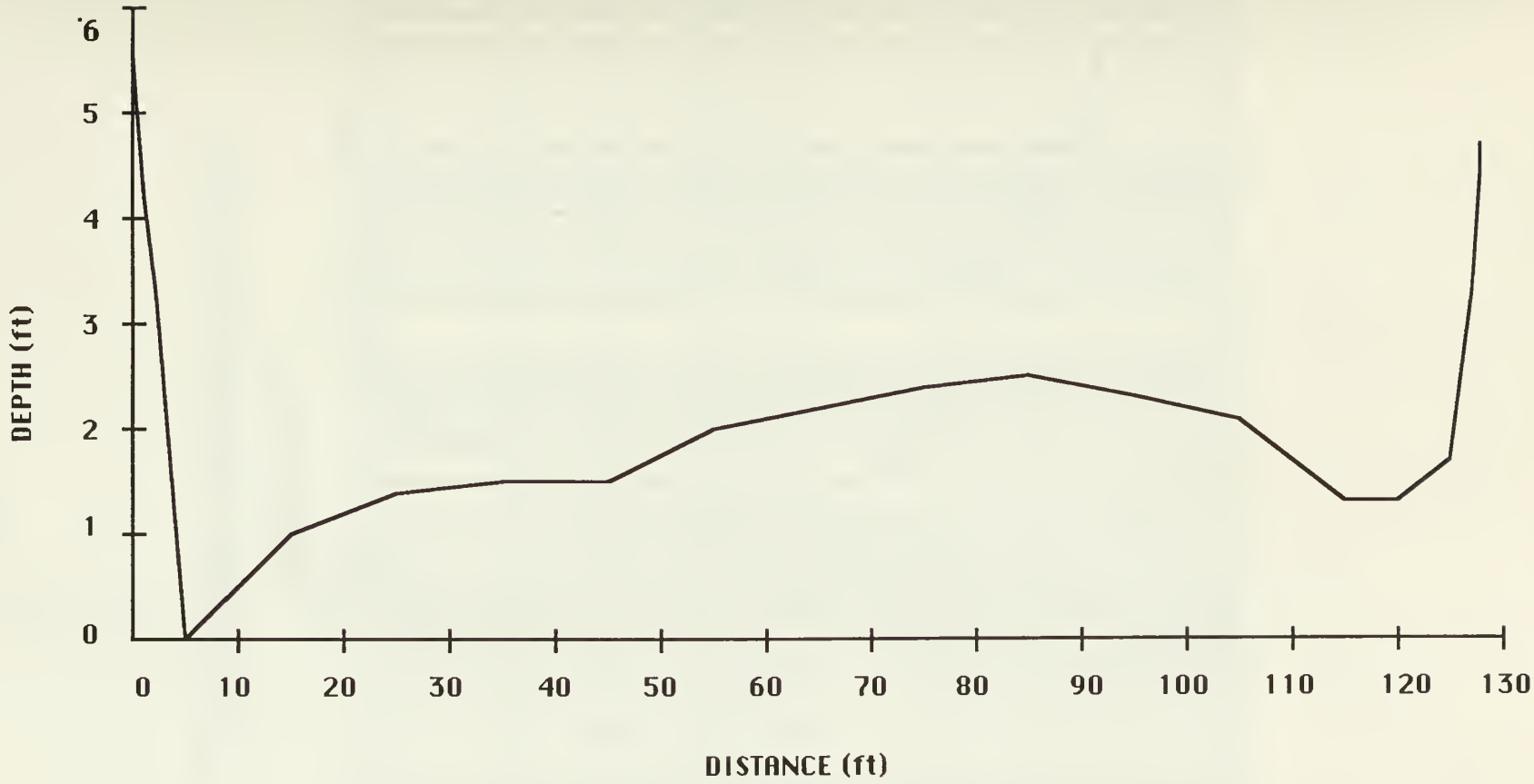
ABOVE ENTRY LOW PT	TAPE DIST	OR VERTICAL DIST	HORIZONTAL DIST	ELEV. X-SECT
1	0.	7.700	0.	5.600
2	1.000	9.100	1.000	4.200
3	2.000	10.000	2.000	3.300
4	5.000	13.300	5.000	0.
5	10.000	12.800	10.000	0.500
6	15.000	12.300	15.000	1.000
7	25.000	11.900	24.999	1.400
8	35.000	11.800	34.999	1.500
9	45.000	11.800	44.999	1.500
10	55.000	11.400	54.999	1.900
11	65.000	11.100	64.998	2.200
12	75.000	10.900	74.998	2.400
13	85.000	10.800	84.998	2.500
14	95.000	11.000	94.998	2.300
15	105.000	11.200	104.997	2.100
16	115.000	12.000	114.997	1.300
17	120.000	12.000	119.997	1.300
18	125.000	11.600	124.997	1.700
19	127.000	10.000	126.997	3.300
20	128.000	8.900	127.997	4.400
21	128.000	8.600	127.997	4.700

Rating Table, Geom 2:

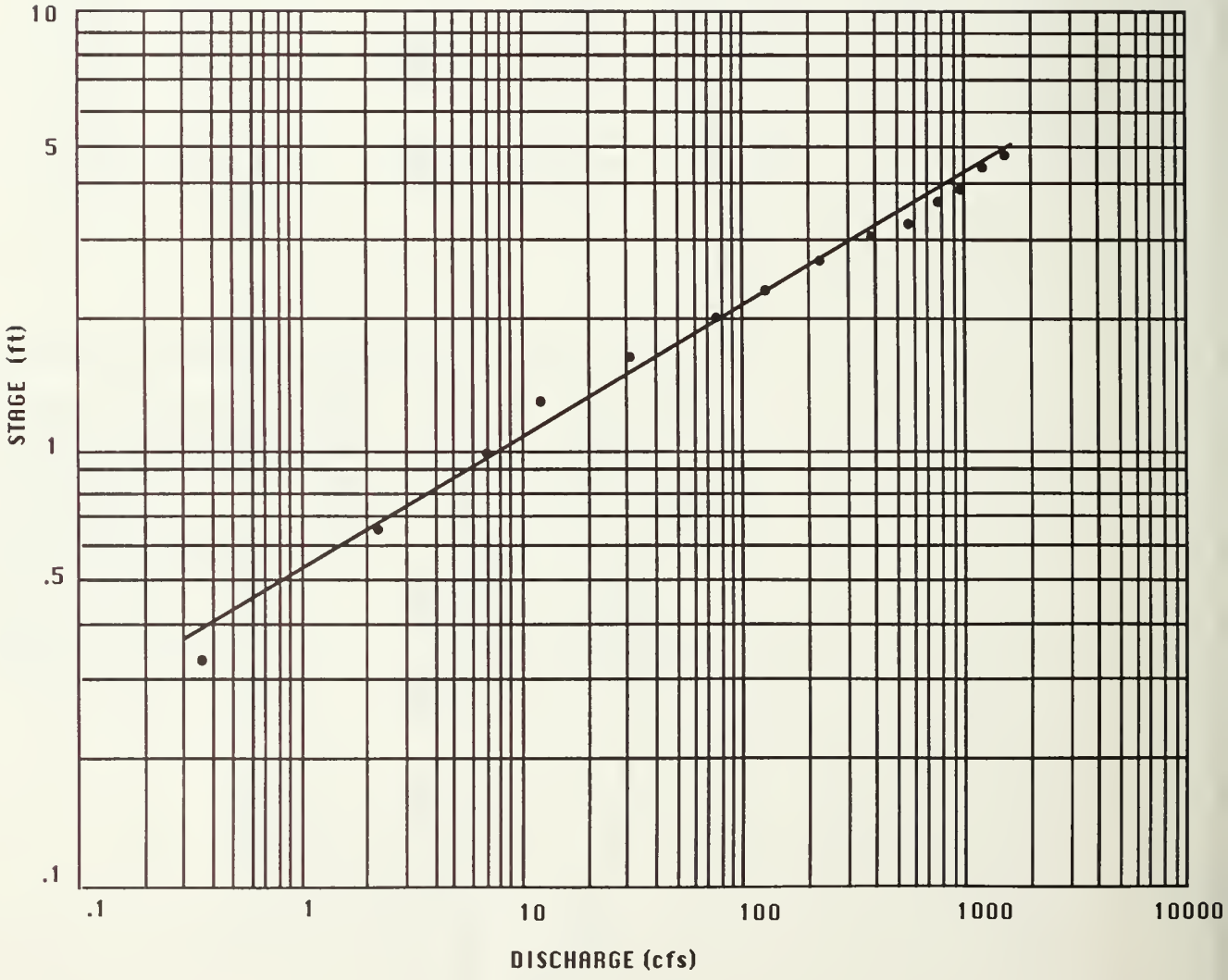
STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.000	0.000	0.003	0.000	0.001	0.000	0.001
0.336	0.355	0.577	0.615	3.828	0.161	3.662
0.671	2.251	0.915	2.459	7.654	0.321	7.324
1.007	6.595	1.192	5.531	11.586	0.477	11.090
1.343	11.853	1.083	10.949	26.506	0.413	19.786
1.678	28.634	1.102	25.988	61.273	0.424	45.982
2.014	70.471	1.449	48.641	76.056	0.640	55.627
2.350	125.039	1.606	77.851	104.290	0.746	69.612
2.685	220.006	1.871	117.603	125.328	0.938	123.670
3.021	362.668	2.278	159.233	126.319	1.261	124.394
3.356	532.410	2.647	201.105	127.304	1.580	125.111
3.692	727.245	2.990	243.211	128.259	1.896	125.789
4.028	945.545	3.311	285.544	129.215	2.210	126.467
4.363	1186.316	3.616	328.099	130.126	2.521	127.080
4.699	1449.022	3.908	370.803	130.887	2.833	127.353

Channel Geometry, Bankfull Stage, Geom 2:

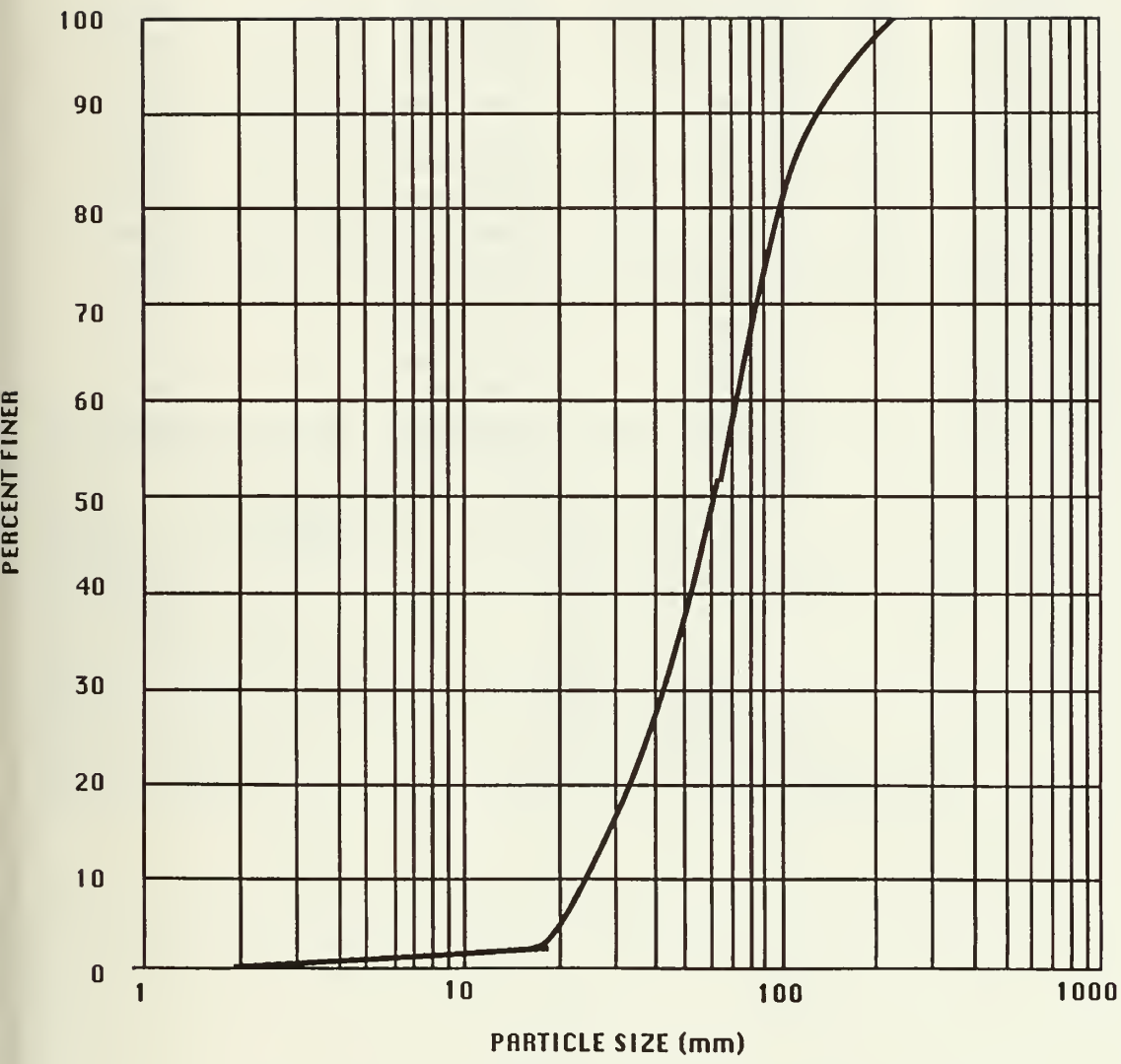
CROSS SECTIONAL AREA =	320.050	SQ FEET
WETTED PERIMETER =	129.963	FEET
HYDRAULIC RADIUS =	2.463	FEET
GRADIENT =	0.0029	FEET/FOOT
MANNINGS N =	0.041	
MAXIMUM DEPTH =	4.300	FEET
MEAN DEPTH =	2.521	FEET
TOP WIDTH =	126.977	FEET
MEAN VELOCITY =	3.559	FEET/SEC
DISCHARGE =	1139.162	CUBIC FEET/SEC



CHANNEL CROSS SECTION, BEAVER CREEK - GEOM 2



INDIRECT RATING CURVE, BEAVER CREEK, GEOM 2



PARTICLE SIZE DISTRIBUTION - BEAVER CREEK, GEOM 2

Beaver Creek, CHANL Program: selected output
Geom-3

Cross Section Data:

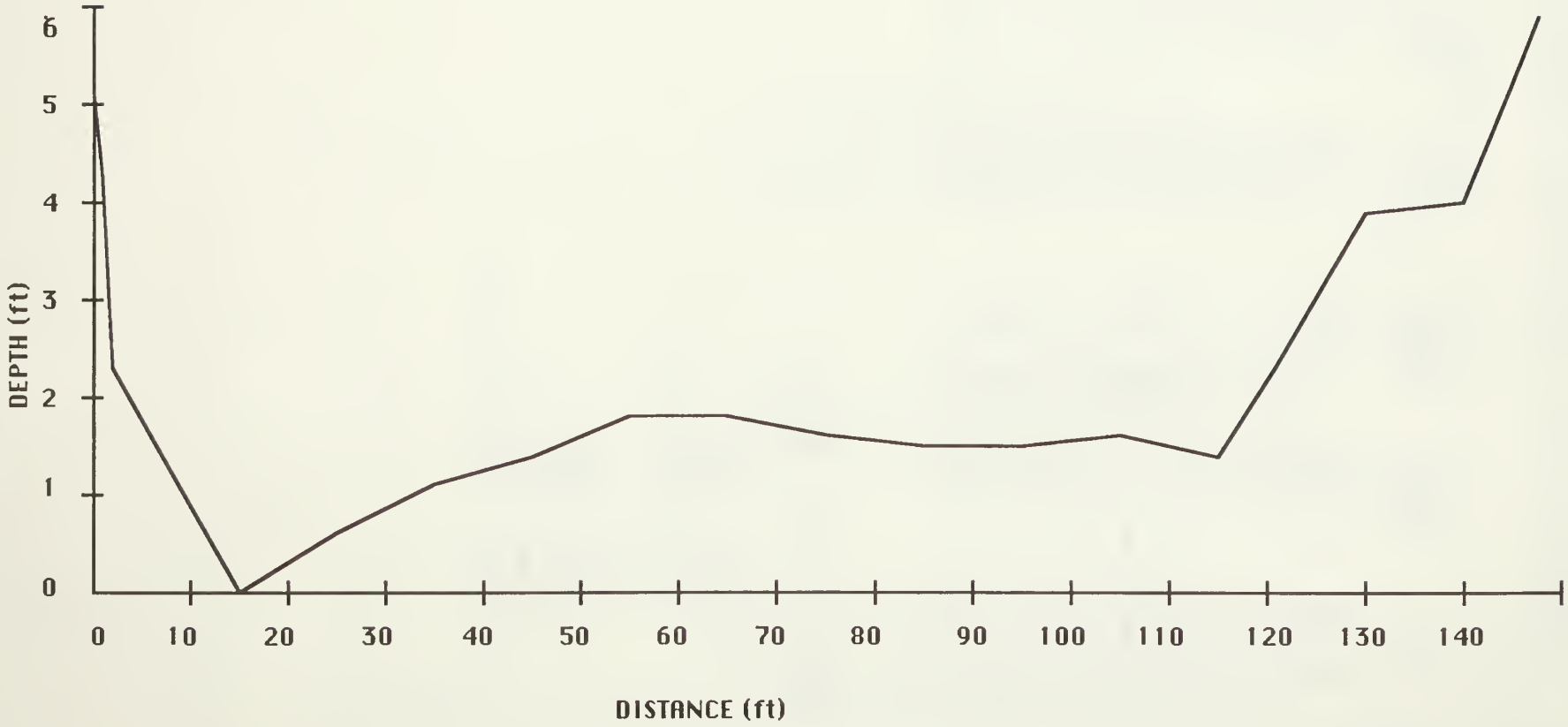
ABOVE ENTRY LOW PT	DIST	DIST	DIST	X-SECT
1	0.	7.200	0.	5.100
2	1.000	8.000	1.000	4.300
3	2.000	10.000	2.000	2.300
4	15.000	12.300	15.000	0.
5	25.000	11.700	25.000	0.600
6	35.000	11.200	34.999	1.100
7	45.000	10.900	44.999	1.400
8	55.000	10.500	54.999	1.800
9	65.000	10.500	64.999	1.800
10	75.000	10.700	74.999	1.600
11	85.000	10.800	84.998	1.500
12	95.000	10.800	94.998	1.500
13	105.000	10.700	104.998	1.600
14	115.000	10.900	114.998	1.400
15	120.500	10.000	120.498	2.300
16	130.000	8.400	129.998	3.900
17	140.000	8.300	139.997	4.000
18	145.000	7.100	144.997	5.200
19	147.000	6.300	146.997	6.000

Rating Table, Geom 3:

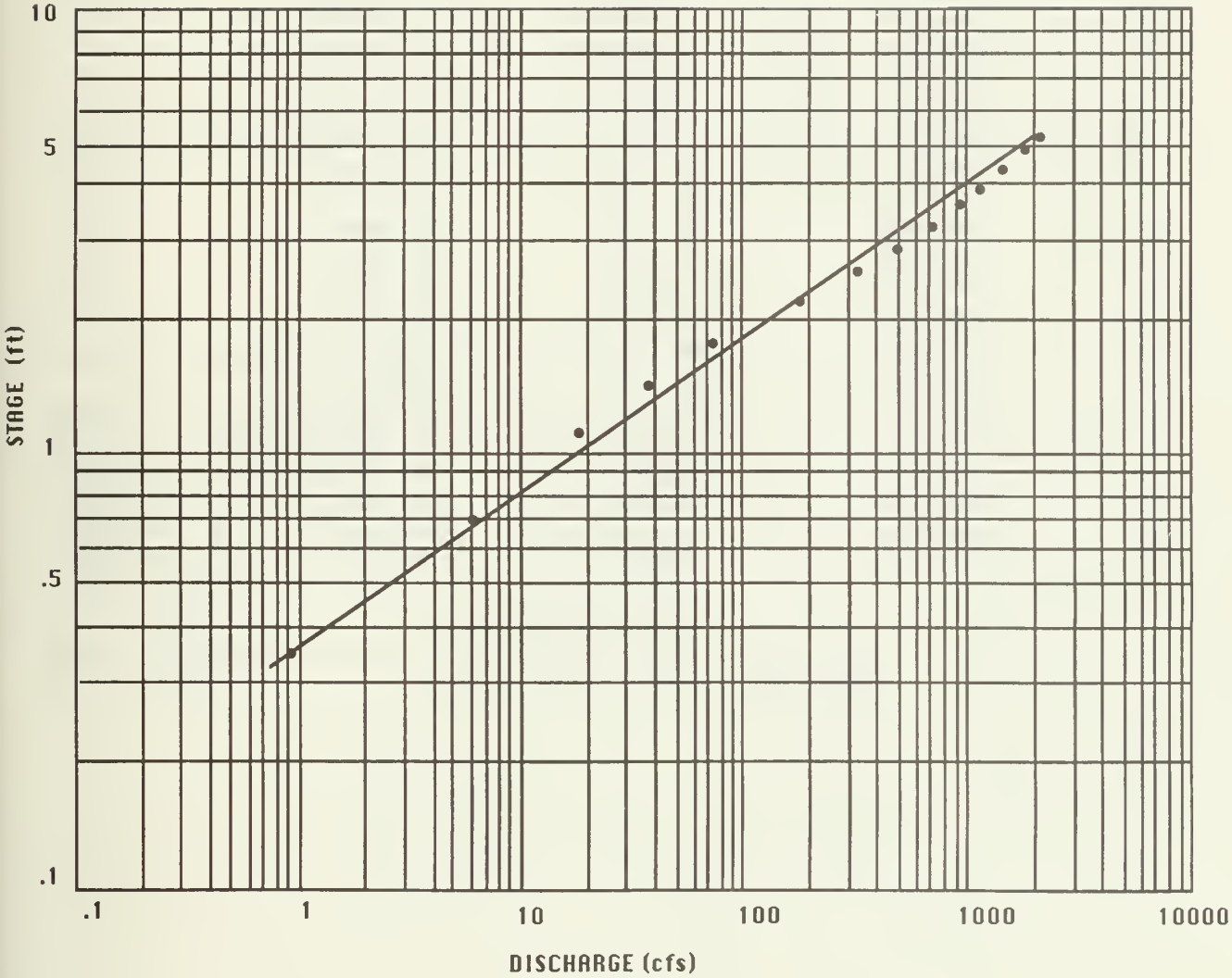
STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.012	0.000	0.022	0.000	0.022
0.365	0.932	0.626	1.488	8.194	0.182	8.151
0.729	5.839	0.979	5.965	16.796	0.355	16.711
1.094	17.477	1.271	13.753	26.180	0.525	26.054
1.458	35.945	1.389	25.877	43.101	0.600	39.686
1.822	68.671	1.223	56.133	113.118	0.496	112.876
2.186	169.584	1.730	98.024	117.464	0.835	117.160
2.551	306.522	2.169	141.309	120.609	1.172	120.110
2.915	475.525	2.564	185.481	123.209	1.505	122.455
3.279	673.654	2.922	230.508	125.809	1.832	124.800
3.643	899.300	3.254	276.389	128.410	2.152	127.144
4.007	1102.442	3.406	323.663	140.395	2.305	138.882
4.372	1393.042	3.719	374.557	142.398	2.630	140.635
4.736	1710.112	4.013	426.138	144.541	2.948	142.608
5.100	2053.777	4.293	478.437	146.685	3.262	144.581

Channel Geometry, Bankfull Stage, Geom-3:

CROSS SECTIONAL AREA =	421.038	SQ FEET
WETTED PERIMETER =	144.331	FEET
HYDRAULIC RADIUS =	2.917	FEET
GRADIENT =	0.0029	FEET/FOOT
MANNINGS N =	0.041	
MAXIMUM DEPTH =	4.700	FEET
MEAN DEPTH =	2.956	FEET
TOP WIDTH =	142.414	FEET
MEAN VELOCITY =	3.985	FEET/SEC
DISCHARGE =	1677.768	CUBIC FEET/SEC



CHANNEL CROSS SECTION, BEAVER CREEK - GEOM 3



INDIRECT RATING CURVE, BEAVER CREEK, GEOM 3

Beaver Creek, CHANL Program: selected output
Geom-4

Cross Section Data:

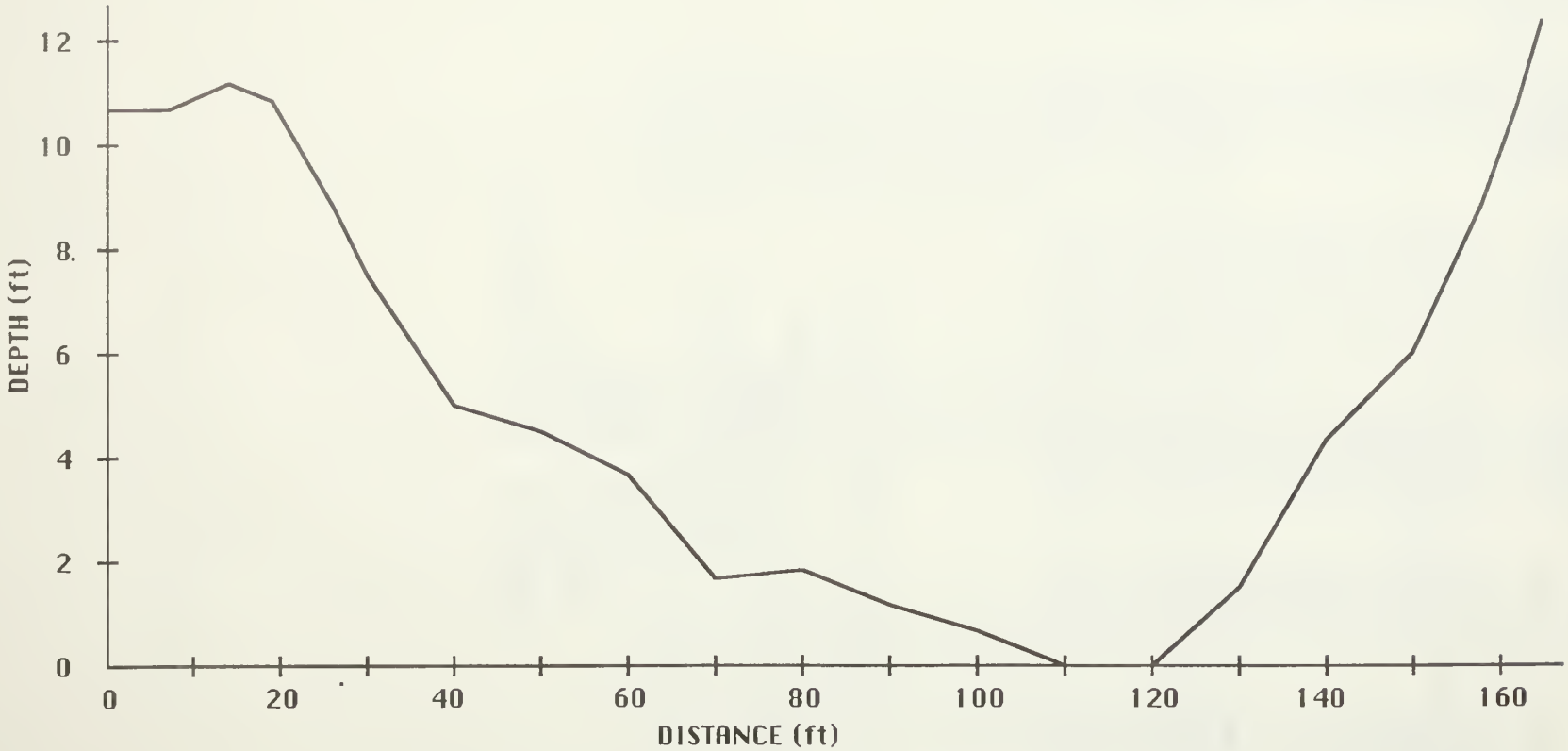
ABOVE ENTRY LOW PT	TAPE DIST	FORESIGHT OR VERTICAL DIST	CORRECTED HORIZONTAL DIST	ELEV. X-SECT
1	0.	8.200	0.	10.600
2	7.000	8.200	7.000	10.600
3	14.000	7.700	13.999	11.100
4	19.000	8.100	18.999	10.700
5	26.000	10.000	25.998	8.800
6	30.000	11.300	29.998	7.500
7	40.000	13.800	39.998	5.000
8	50.000	14.400	49.997	4.400
9	60.000	15.100	59.996	3.700
10	70.000	17.100	69.996	1.700
11	80.000	17.000	79.995	1.800
12	90.000	17.700	89.995	1.100
13	100.000	18.200	99.994	0.600
14	110.000	18.800	109.993	0.
15	120.000	18.800	119.993	0.
16	130.000	17.300	129.992	1.500
17	140.000	14.400	139.992	4.400
18	150.000	12.800	149.991	6.000
19	158.500	10.000	158.491	8.800
20	162.500	8.100	162.490	10.700
21	165.000	6.400	164.990	12.400

Rating Table, Geom-4:

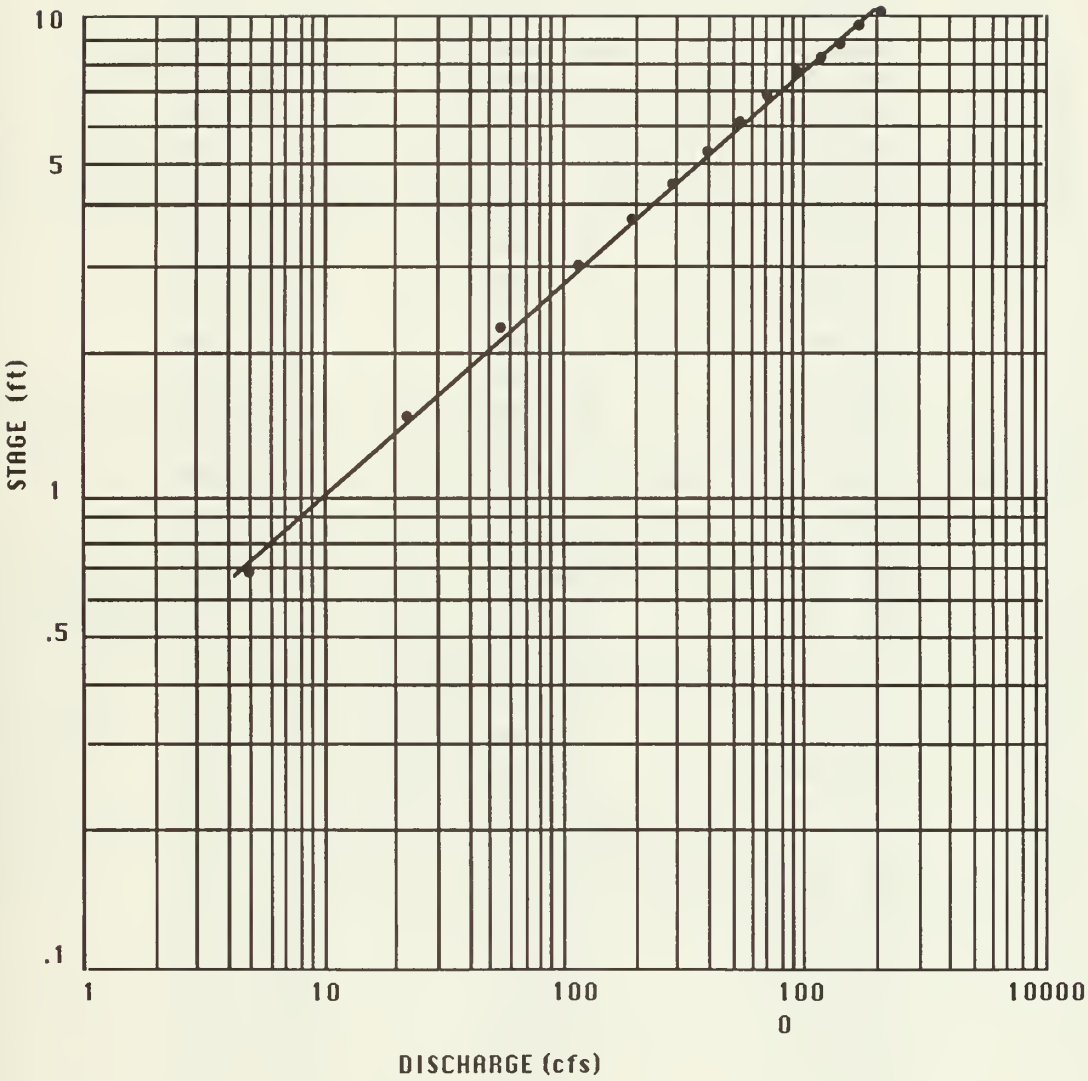
STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.006	0.010	10.023	0.001	10.023
0.758	5.713	0.399	14.326	28.292	0.506	28.214
1.515	25.590	0.597	42.835	46.139	0.928	45.980
2.272	65.977	0.757	87.174	65.854	1.324	65.520
3.029	135.073	0.970	139.199	72.432	1.922	71.916
3.786	224.164	1.143	196.099	79.806	2.457	79.113
4.543	323.717	1.240	261.129	94.099	2.775	93.281
5.301	454.109	1.345	337.745	107.752	3.134	106.824
6.058	627.378	1.488	421.550	115.485	3.650	114.398
6.815	835.749	1.638	510.174	121.026	4.215	119.724
7.572	1071.648	1.778	602.827	126.503	4.765	124.984
8.329	1338.033	1.914	699.201	131.372	5.322	129.612
9.086	1632.060	2.042	799.065	136.160	5.869	134.147
9.843	1954.064	2.166	902.283	140.814	6.408	138.530
10.600	2303.074	2.283	1008.819	145.468	6.935	142.913

Channel Geometry, Bankfull Stage, Geom-4:

```
CROSS SECTIONAL AREA =1008.819  SQ FEET
WETTED PERIMETER =     145.468  FEET
HYDRAULIC RADIUS =       6.935  FEET
GRADIENT =               0.0003 FEET/FOOT
MANNINGS N =             0.041
MAXIMUM DEPTH =         10.600  FEET
MEAN DEPTH =             7.059  FEET
TOP WIDTH =            142.913  FEET
MEAN VELOCITY =          2.283  FEET/SEC
DISCHARGE =           2303.074  CUBIC FEET/SEC
```



CHANNEL CROSS SECTION, BEAVER CREEK - GEOM 4



INDIRECT RATING CURVE - BEAVER CREEK, GEOM 4

Beaver Creek, CHANL Program: selected output
Geom-5

Cross Section Data:

ABOVE ENTRY LOW PT	TAPE DIST	FORESIGHT OR VERTICAL DIST	CORRECTED HORIZONTAL DIST	ELEV. X-SECT
1	0.	6.800	0.	7.200
2	3.500	7.500	3.500	6.500
3	7.000	10.000	7.000	4.000
4	15.000	12.500	15.000	1.500
5	25.000	13.500	25.000	0.500
6	35.000	14.000	35.000	0.
7	45.000	14.000	45.000	0.
8	55.000	13.500	55.000	0.500
9	65.000	13.500	65.000	0.500
10	75.000	13.500	75.000	0.500
11	85.000	13.000	85.000	1.000
12	95.000	13.000	95.000	1.000
13	105.000	12.500	105.000	1.500
14	115.000	13.000	115.000	1.000
15	125.000	13.000	125.000	1.000
16	135.000	12.500	135.000	1.500
17	145.000	12.000	145.000	2.000
18	155.000	12.000	155.000	2.000
19	165.000	11.000	165.000	3.000
20	175.000	10.500	175.000	3.500
21	183.000	10.000	183.000	4.000
22	183.000	10.000	183.000	4.000
23	195.000	9.600	195.000	4.400
24	205.000	9.400	205.000	4.600
25	215.000	8.300	215.000	5.700
26	225.000	8.300	225.000	5.700
27	235.000	8.500	235.000	5.500
28	245.000	8.100	245.000	5.900
29	255.000	7.200	255.000	6.800
30	265.000	6.100	265.000	7.900
31	275.000	4.800	275.000	9.200
32	285.000	5.100	285.000	8.900
33	295.000	5.500	295.000	8.500
34	305.000	5.700	305.000	8.300
35	315.000	6.000	315.000	8.000
36	325.000	5.800	325.000	8.200
37	335.000	6.500	335.000	7.500
38	340.000	6.300	340.000	7.700
39	350.000	7.800	350.000	6.200
40	360.000	10.400	360.000	3.600
41	370.000	11.100	370.000	2.900
42	380.000	11.200	380.000	2.800
43	390.000	11.300	390.000	2.700
44	396.500	11.000	396.500	3.000
45	402.000	6.200	402.000	7.800

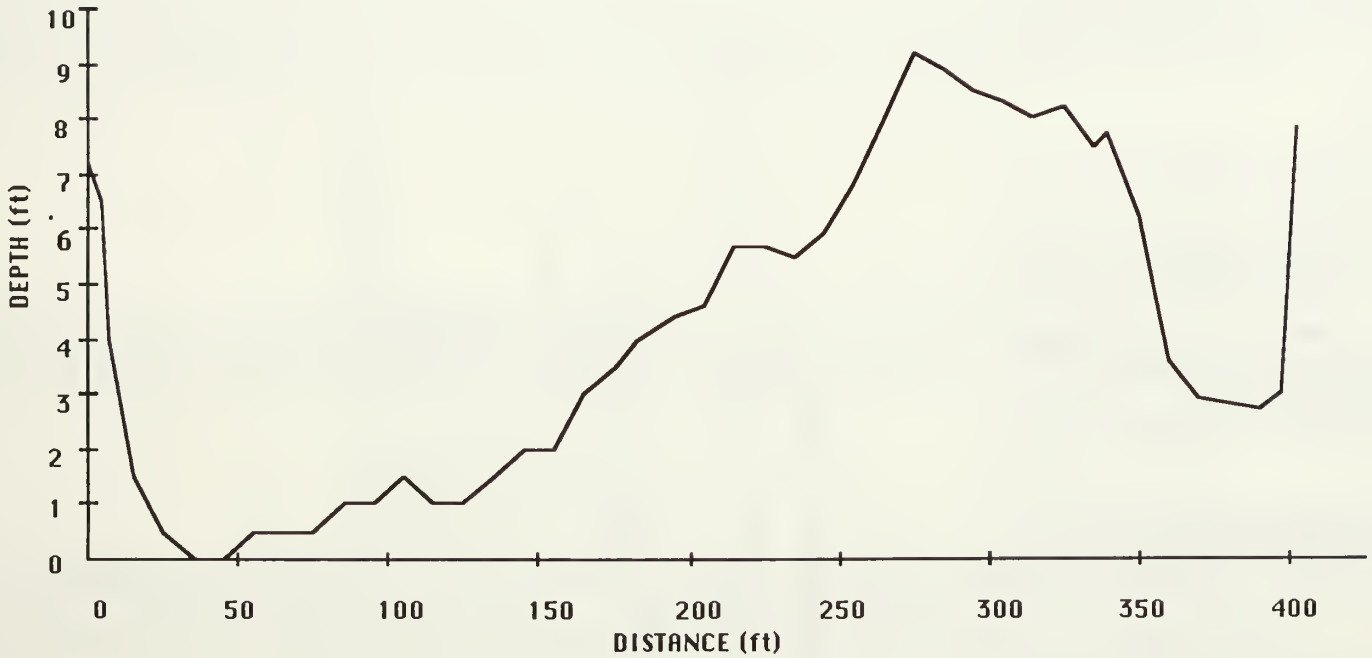
Rating Table, Geom 5:

STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.020	0.010	10.040	0.001	10.040
0.515	7.623	0.708	10.761	50.480	0.213	50.454
1.029	49.786	1.206	41.269	87.116	0.474	75.878
1.543	161.034	1.691	95.233	121.140	0.786	121.007
2.058	346.834	2.153	161.074	142.585	1.130	142.360
2.572	635.289	2.692	236.012	149.476	1.579	149.146
3.086	919.777	2.857	321.977	186.523	1.726	186.045
3.600	1353.827	3.203	422.717	206.288	2.049	205.507
4.114	1897.814	3.570	531.654	220.489	2.411	219.338
4.628	2484.529	3.824	649.740	243.040	2.673	241.457
5.142	3264.858	4.208	775.930	251.452	3.086	249.418
5.657	4023.608	4.436	907.131	271.611	3.340	269.121
6.171	4876.646	4.622	1055.109	297.001	3.553	294.067
6.685	5967.029	4.935	1209.008	308.413	3.920	305.099
7.199	7157.723	5.229	1368.874	320.216	4.275	316.593

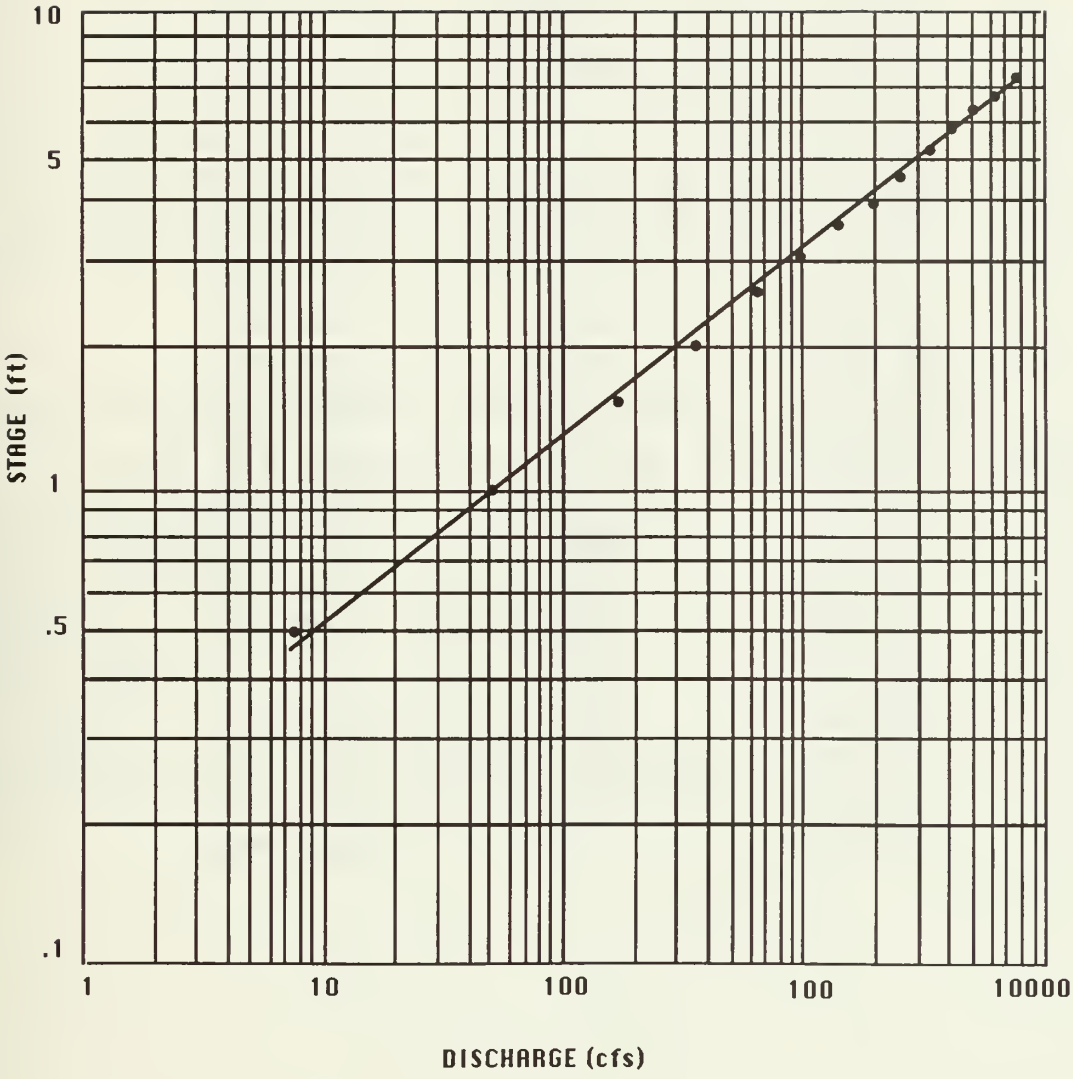
Channel Geometry, Bankfull Stage:

*********THERE ARE MULTIPLE CHANNELS AT THIS STAGE. MANNINGS

```
CROSS SECTIONAL AREA =1005.163  SQ FEET
WETTED PERIMETER =     293.865  FEET
HYDRAULIC RADIUS =       3.420  FEET
GRADIENT =               0.0030 FEET/FOOT
MANNINGS N =             0.041
MAXIMUM DEPTH =          6.000  FEET
MEAN DEPTH =             4.155  FEET
TOP WIDTH =            241.911  FEET
MEAN VELOCITY =          4.507  FEET/SEC
DISCHARGE =           4529.947  CUBIC FEET/SEC
```



CHANNEL CROSS SECTION, BEAVER CREEK - GEOM 5



INDIRECT RATING CURVE - BEAVER CREEK, GEOM 5

Beaver Creek, CHANL Program: selected output
Geom-6

Cross Section Data:

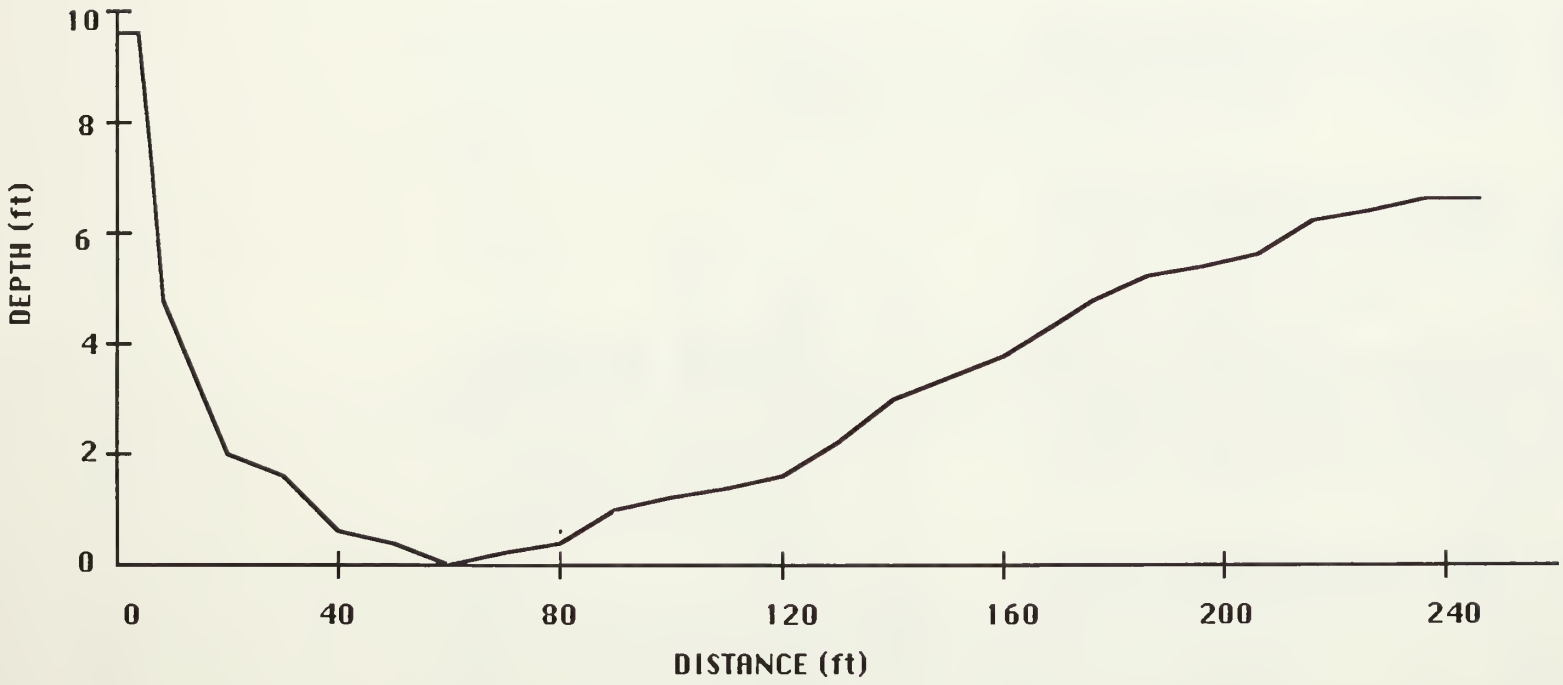
ABOVE ENTRY LOW PT	TAPE DIST	FORESIGHT OR VERTICAL DIST	CORRECTED HORIZONTAL DIST	ELEV. X-SECT
1	0.	5.200	0.	9.600
2	4.000	5.200	4.000	9.600
3	5.500	7.400	5.500	7.400
4	7.000	10.000	6.999	4.800
5	20.000	12.800	19.998	2.000
6	30.000	13.200	29.998	1.600
7	40.000	14.200	39.997	0.600
8	50.000	14.300	49.996	0.500
9	60.000	14.800	59.995	0.
10	70.000	14.500	69.994	0.300
11	80.000	14.300	79.994	0.500
12	90.000	13.800	89.993	1.000
13	100.000	13.700	99.992	1.100
14	110.000	13.300	109.991	1.500
15	120.000	13.200	119.990	1.600
16	130.000	12.700	129.990	2.100
17	140.000	11.800	139.989	3.000
18	150.000	11.500	149.988	3.300
19	160.000	11.000	159.987	3.800
20	170.000	10.300	169.986	4.500
21	175.000	10.000	174.986	4.800
22	185.000	9.600	184.985	5.200
23	195.000	9.300	194.984	5.500
24	205.000	9.200	204.984	5.600
25	215.000	8.700	214.983	6.100
26	225.000	8.400	224.982	6.400
27	235.000	8.300	234.981	6.500
28	245.000	8.300	244.980	6.500

Rating Table, Geom 6:

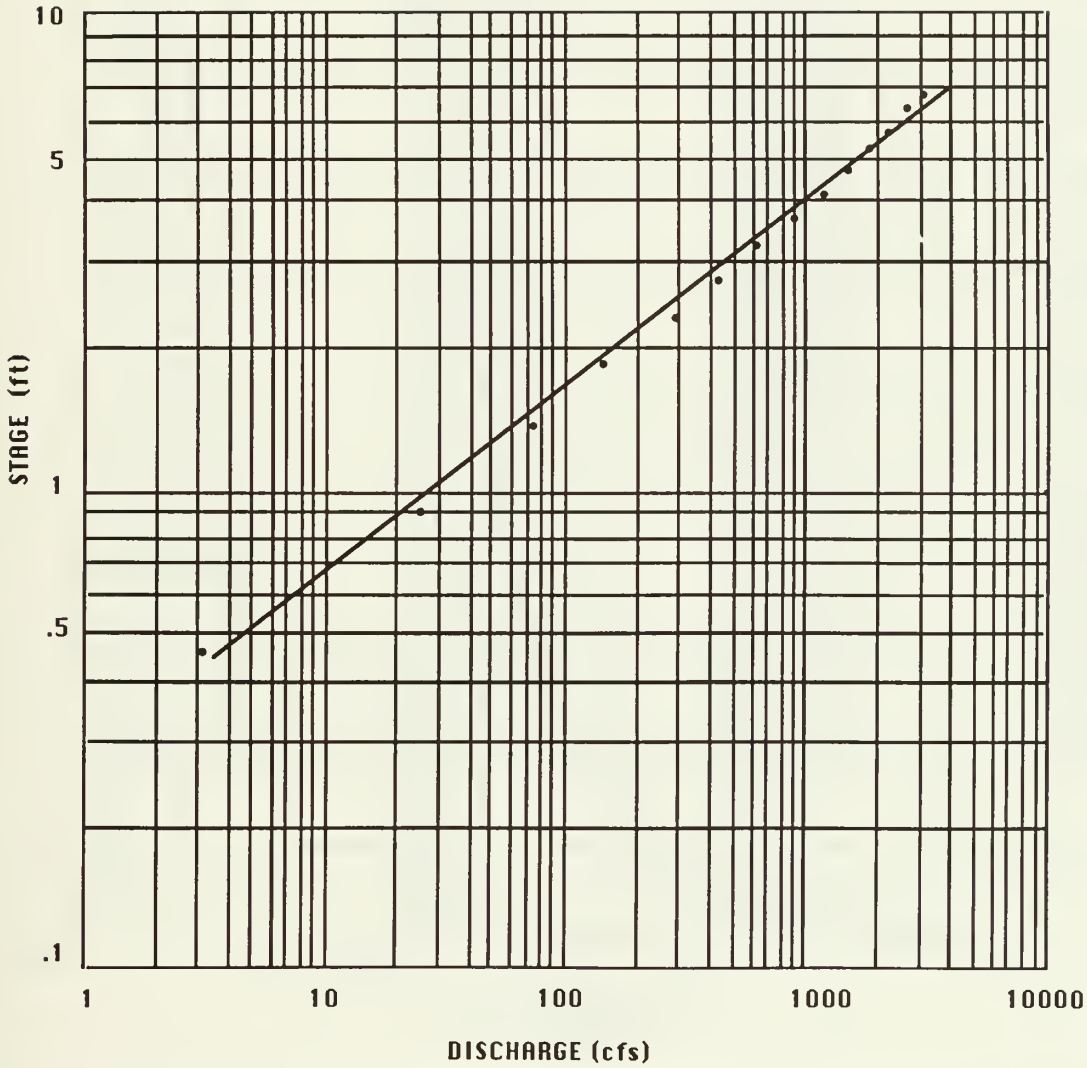
STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.010	0.000	0.053	0.000	0.053
0.465	3.515	0.586	5.996	27.576	0.217	27.558
0.929	26.668	1.024	26.054	51.921	0.502	51.874
1.393	75.202	1.335	56.325	75.342	0.748	75.264
1.858	154.106	1.578	97.666	101.685	0.960	101.583
2.322	286.566	1.931	148.390	114.104	1.300	113.948
2.786	463.240	2.282	202.975	121.485	1.671	121.260
3.250	661.173	2.527	261.648	134.415	1.947	134.126
3.714	904.235	2.767	326.849	146.579	2.230	146.230
4.178	1199.701	3.022	396.965	155.919	2.546	155.505
4.642	1536.700	3.261	471.205	165.108	2.854	164.629
5.107	1902.491	3.458	550.112	176.511	3.117	175.827
5.571	2251.326	3.544	635.215	196.459	3.233	195.500
6.035	2722.295	3.733	729.224	208.630	3.495	207.393
6.499	3155.955	3.807	829.088	230.374	3.599	228.862

Channel Geometry, Bankfull Stage, Geom-6:

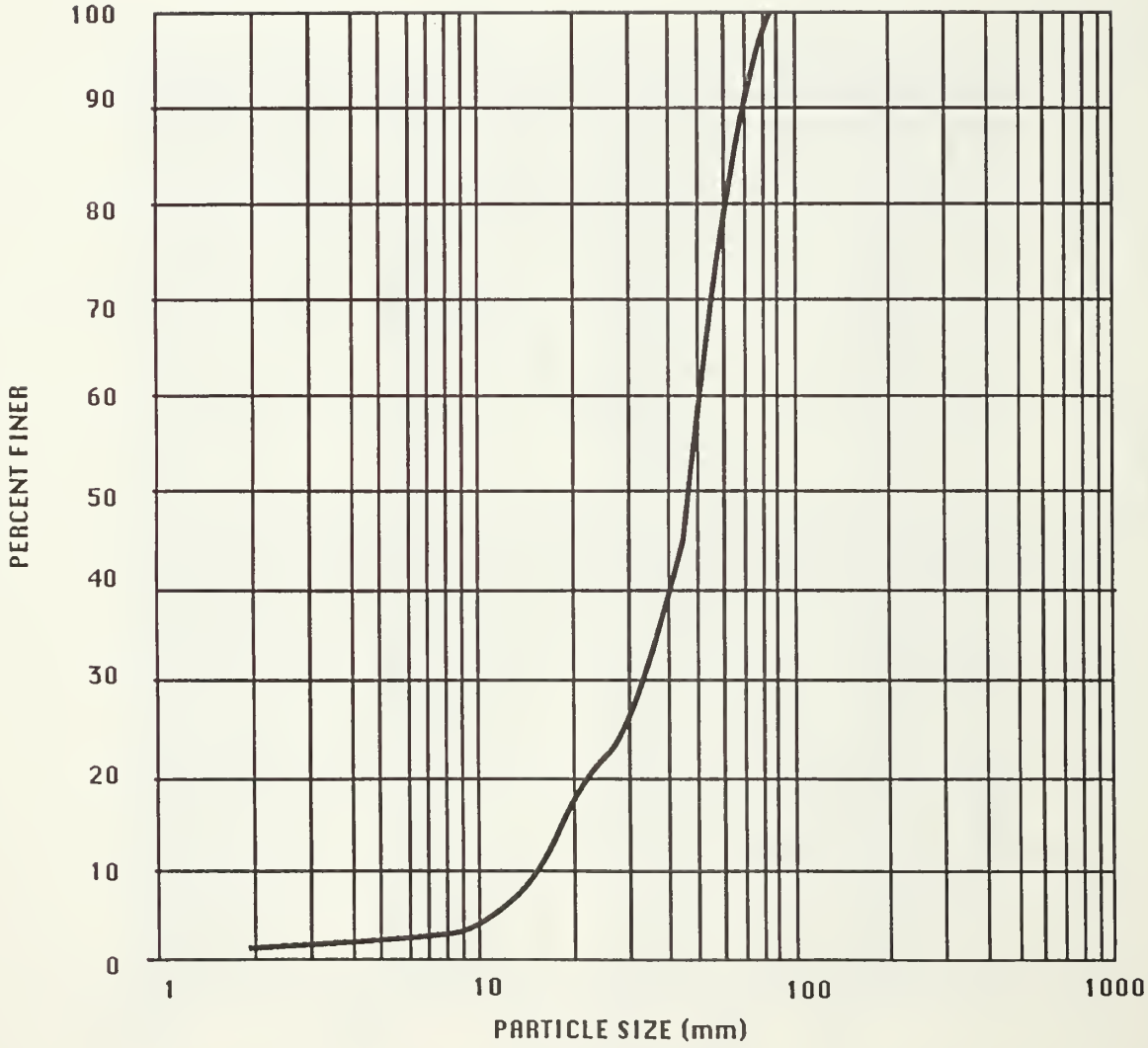
```
*********THERE ARE MULTIPLE CHANNELS AT THIS STAGE.    MANNINGS
CROSS SECTIONAL AREA = 829.317  SQ FEET
WETTED PERIMETER =     230.475  FEET
HYDRAULIC RADIUS =       3.598  FEET
GRADIENT =               0.0020 FEET/FOOT
MANNINGS N =             0.041
MAXIMUM DEPTH =          6.500  FEET
MEAN DEPTH =             3.622  FEET
TOP WIDTH =            228.962  FEET
MEAN VELOCITY =          3.806  FEET/SEC
DISCHARGE =           3156.483  CUBIC FEET/SEC
```



CHANNEL CROSS SECTION, BEAVER CREEK - GEOM 6



INDIRECT RATING CURVE - BEAVER CREEK, GEOM 6



PARTICLE SIZE DISTRIBUTION - BEAVER CREEK, GEOM 6

Beaver Creek, CHANL Program: selected output
Geom-7

Cross Section Data:

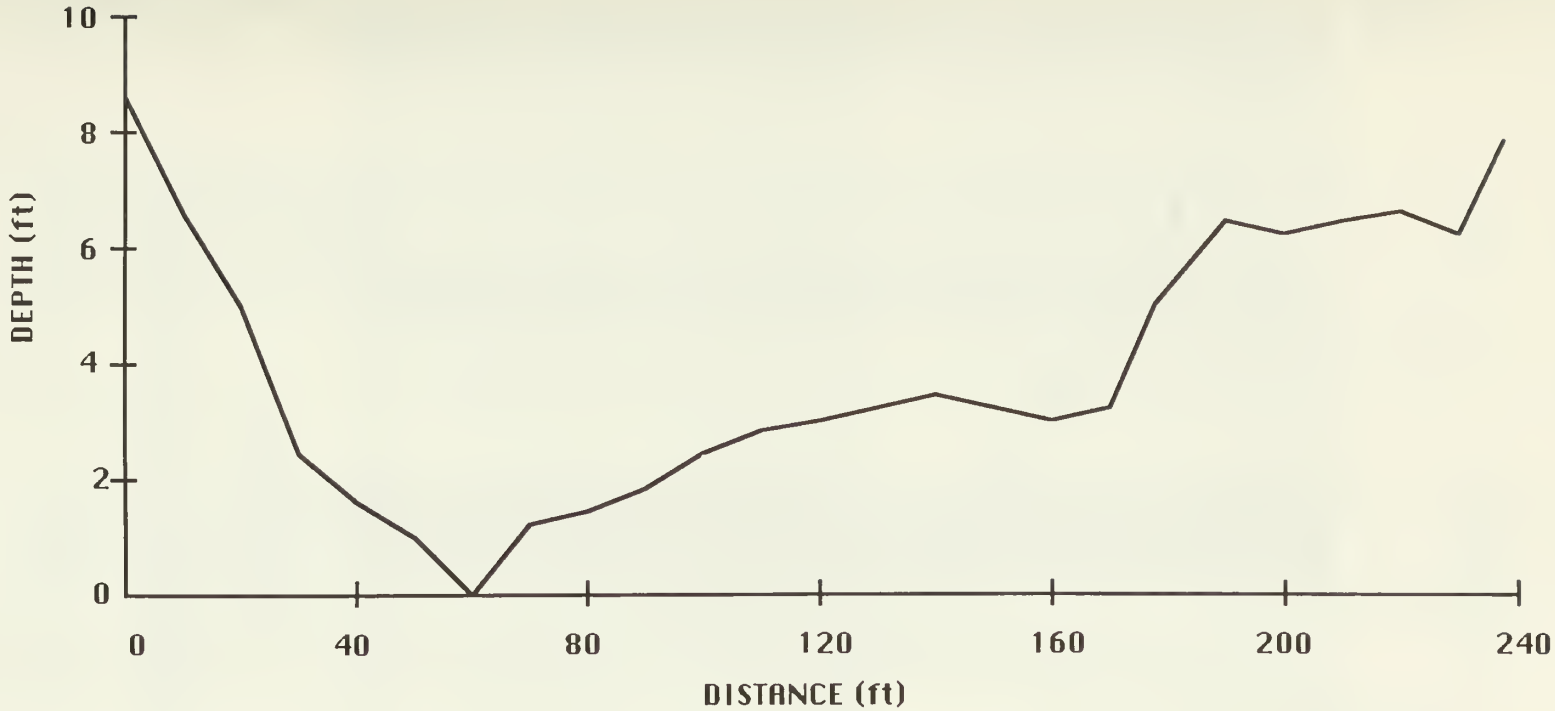
ABOVE ENTRY LOW PT	TAPE DIST	FORESIGHT OR VERTICAL DIST	CORRECTED HORIZONTAL DIST	ELEV. X-SECT
1	0.	6.400	0.	8.600
2	10.000	8.400	10.000	6.600
3	20.000	10.000	20.000	5.000
4	30.000	12.700	30.000	2.300
5	40.000	13.300	40.000	1.700
6	50.000	14.000	50.000	1.000
7	60.000	15.000	60.000	0.
8	70.000	13.900	70.000	1.100
9	80.000	13.500	80.000	1.500
10	90.000	13.200	89.999	1.800
11	100.000	12.600	99.999	2.400
12	110.000	12.200	109.999	2.800
13	120.000	11.900	119.999	3.100
14	130.000	11.800	129.999	3.200
15	140.000	11.700	139.999	3.300
16	150.000	11.800	149.999	3.200
17	160.000	12.000	159.999	3.000
18	170.000	11.800	169.999	3.200
19	179.000	10.000	178.999	5.000
20	190.000	8.600	189.999	6.400
21	200.000	8.800	199.999	6.200
22	210.000	8.600	209.999	6.400
23	220.000	8.400	219.999	6.600
24	230.000	8.800	229.999	6.200
25	238.000	7.200	237.999	7.800

Rating Table, Geom-7:

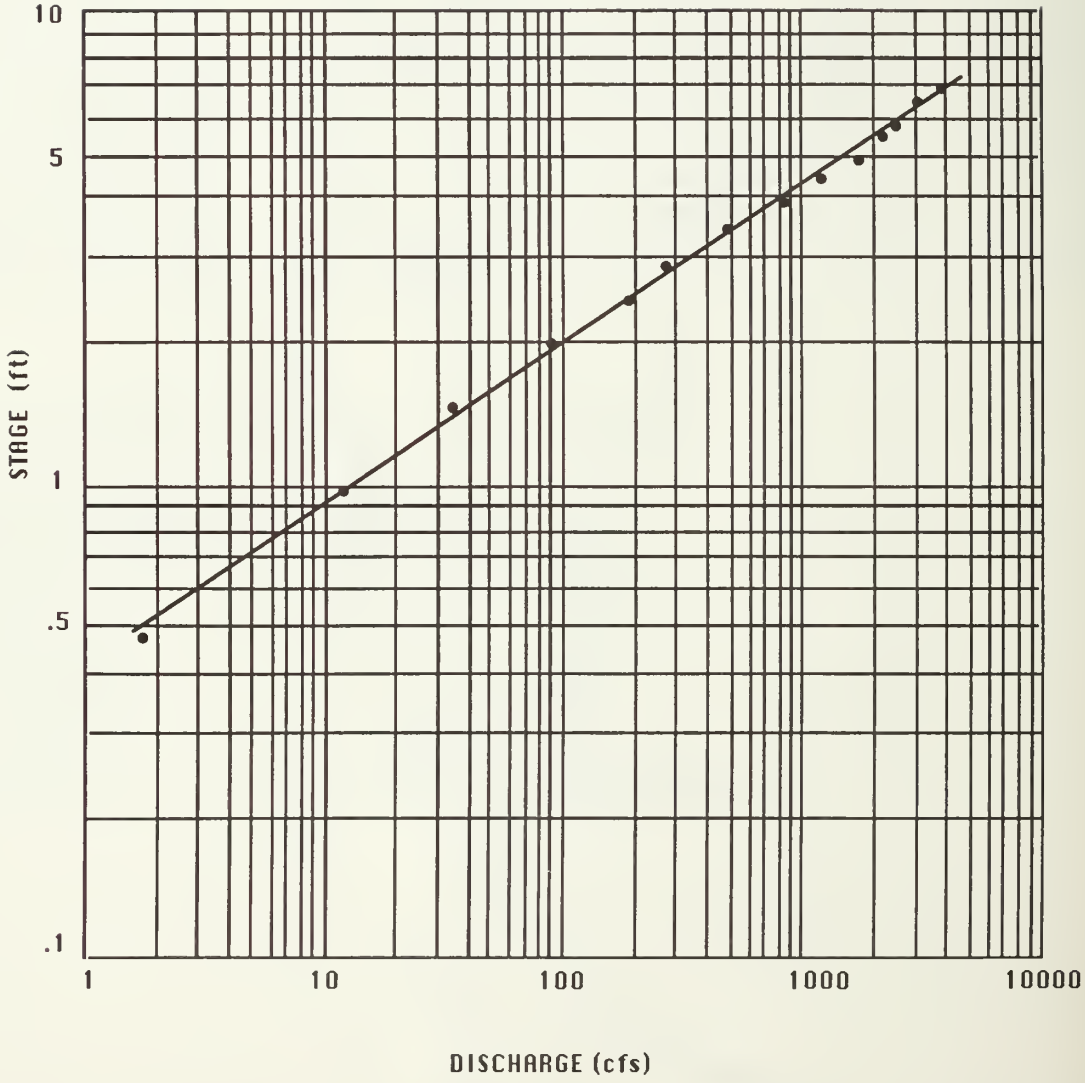
STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.012	0.000	0.019	0.000	0.019
0.558	2.425	0.816	2.972	10.711	0.277	10.653
1.115	15.085	1.268	11.897	22.132	0.538	22.018
1.672	44.521	1.466	30.378	45.477	0.668	45.333
2.229	113.324	1.833	61.815	66.142	0.935	65.966
2.786	229.848	2.235	102.819	81.705	1.258	81.450
3.343	333.202	2.062	161.585	144.931	1.115	144.577
3.900	645.146	2.650	243.464	149.908	1.624	149.425
4.457	1037.601	3.163	328.044	154.885	2.118	154.273
5.014	1504.866	3.623	415.325	159.936	2.597	159.197
5.571	2026.180	4.003	506.186	167.873	3.015	167.054
6.128	2618.705	4.354	601.423	175.810	3.421	174.912
6.685	2964.900	4.154	713.702	223.873	3.188	222.849
7.242	3820.837	4.552	839.380	229.553	3.657	228.419
7.799	4768.656	4.925	968.161	235.233	4.116	233.989

Channel Geometry, Bankfull Stage, Geom-7:

CROSS SECTIONAL AREA =	968.161	SQ FEET
WETTED PERIMETER =	235.233	FEET
HYDRAULIC RADIUS =	4.116	FEET
GRADIENT =	0.0028	FEET/FOOT
MANNINGS N =	0.041	
MAXIMUM DEPTH =	7.799	FEET
MEAN DEPTH =	4.138	FEET
TOP WIDTH =	233.989	FEET
MEAN VELOCITY =	4.925	FEET/SEC
DISCHARGE =	4768.656	CUBIC FEET/SEC



CHANNEL CROSS SECTION, BEAVER CREEK - GEOM 7



INDIRECT RATING CURVE - BEAVER CREEK, GEOM 7

Beaver Creek, CHANL Program: selected output
Geom-8

Cross Section Data:

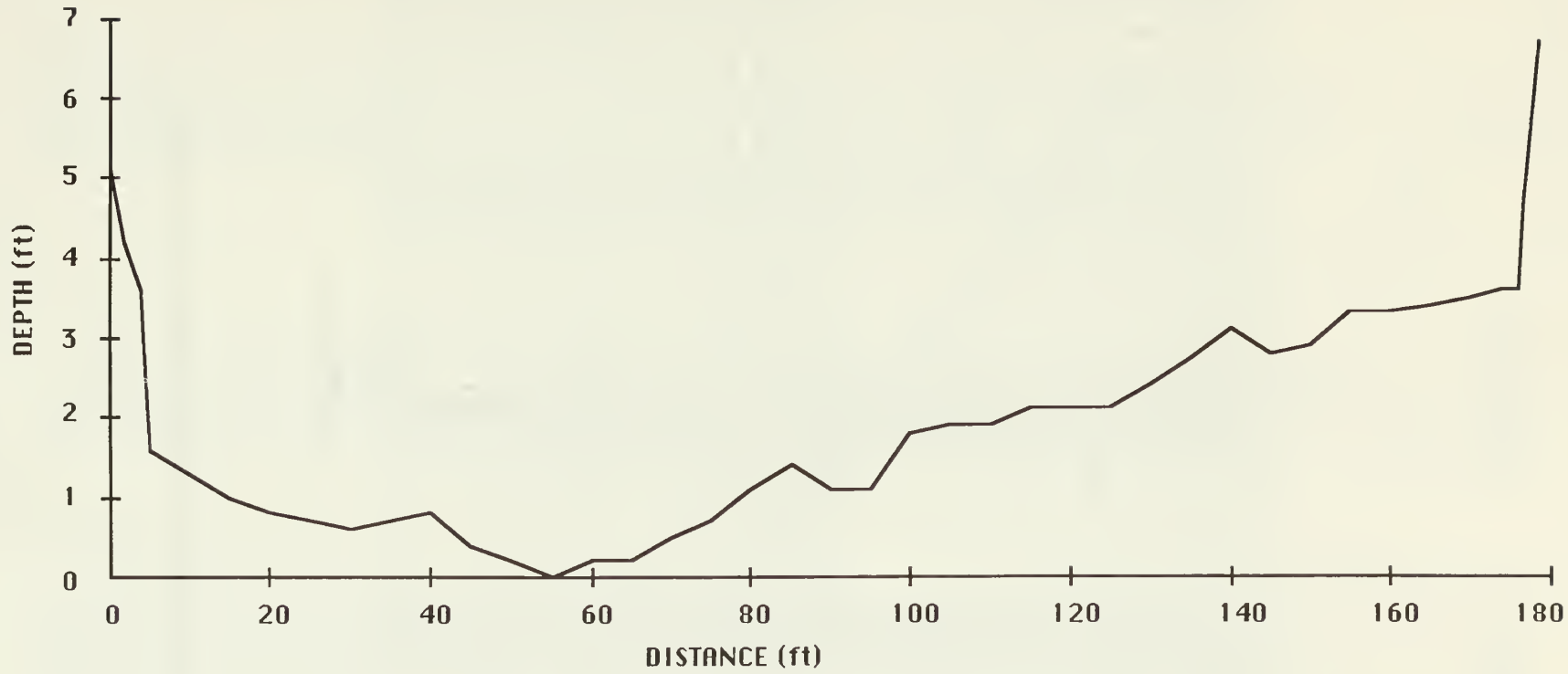
ABOVE ENTRY LOW PT	TAPE DIST	FORESIGHT OR VERTICAL DIST	CORRECTED HORIZONTAL DIST	ELEV. X-SECT
1	0.	8.500	0.	5.100
2	2.000	9.400	2.000	4.200
3	4.000	10.000	4.000	3.600
4	5.000	12.000	5.000	1.600
5	15.000	12.600	14.999	1.000
6	20.000	12.800	19.999	0.800
7	25.000	12.900	24.999	0.700
8	30.000	13.000	29.999	0.600
9	35.000	12.900	34.999	0.700
10	40.000	12.800	39.998	0.800
11	45.000	13.200	44.998	0.400
12	50.000	13.400	49.998	0.200
13	55.000	13.600	54.998	0.
14	60.000	13.400	59.998	0.200
15	65.000	13.400	64.997	0.200
16	70.000	13.100	69.997	0.500
17	75.000	12.900	74.997	0.700
18	80.000	12.500	79.997	1.100
19	85.000	12.200	84.997	1.400
20	90.000	12.500	89.996	1.100
21	95.000	12.500	94.996	1.100
22	100.000	11.800	99.996	1.800
23	105.000	11.700	104.996	1.900
24	110.000	11.700	109.996	1.900
25	115.000	11.500	114.995	2.100
26	120.000	11.500	119.995	2.100
27	125.000	11.500	124.995	2.100
28	130.000	11.200	129.995	2.400
29	135.000	10.900	134.995	2.700
30	140.000	10.500	139.994	3.100
31	145.000	10.800	144.994	2.800
32	150.000	10.700	149.994	2.900
33	155.000	10.300	154.994	3.300
34	160.000	10.300	159.994	3.300
35	165.000	10.250	164.993	3.350
36	170.000	10.100	169.993	3.500
37	174.000	10.000	173.993	3.600
38	176.000	10.000	175.993	3.600
39	177.000	8.900	176.993	4.700
40	179.000	6.900	178.993	6.700

Rating Table, Geom-8:

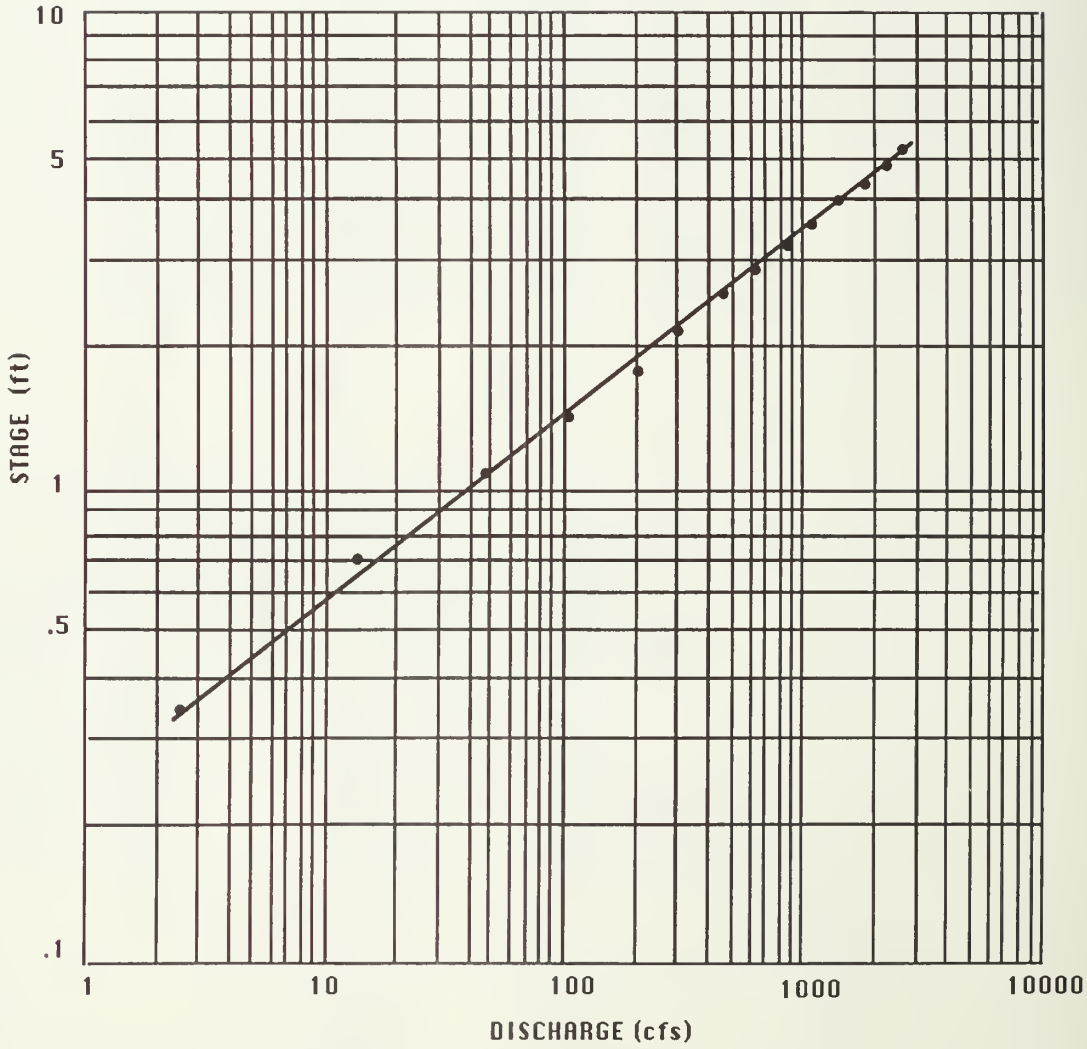
STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.012	0.000	0.050	0.000	0.050
0.365	2.606	0.644	4.047	21.899	0.185	21.883
0.729	14.051	0.927	15.153	47.469	0.319	12.942
1.094	49.461	1.340	36.909	66.546	0.555	66.479
1.458	107.869	1.620	66.580	90.305	0.737	90.183
1.822	205.386	2.041	100.617	96.498	1.043	96.211
2.186	305.113	2.176	140.247	122.246	1.147	121.726
2.551	470.721	2.535	185.720	128.734	1.443	127.978
2.915	648.935	2.776	233.808	141.430	1.653	133.336
3.279	872.496	3.037	287.285	151.821	1.892	150.570
3.643	1093.410	3.150	347.111	173.656	1.999	172.176
4.007	1434.066	3.497	410.101	175.416	2.338	173.721
4.372	1812.305	3.826	473.638	176.996	2.676	175.076
4.736	2226.805	4.142	537.611	178.378	3.014	176.219
5.100	2674.871	4.443	602.006	179.781	3.349	177.393

Channel Geometry, Bankfull Stage:

CROSS SECTIONAL AREA =	478.616	SQ FEET
WETTED PERIMETER =	177.104	FEET
HYDRAULIC RADIUS =	2.702	FEET
GRADIENT =	0.0030	FEET/FOOT
MANNINGS N =	0.041	
MAXIMUM DEPTH =	4.400	FEET
MEAN DEPTH =	2.732	FEET
TOP WIDTH =	175.165	FEET
MEAN VELOCITY =	3.852	FEET/SEC
DISCHARGE =	1843.417	CUBIC FEET/SEC



CHANNEL CROSS SECTION, BEAVER CREEK - GEOM 8



INDIRECT RATING CURVE - BEAVER CREEK, GEOM 8

Beaver Creek, CHANL Program: selected output
Geom-9

Cross Section Data:

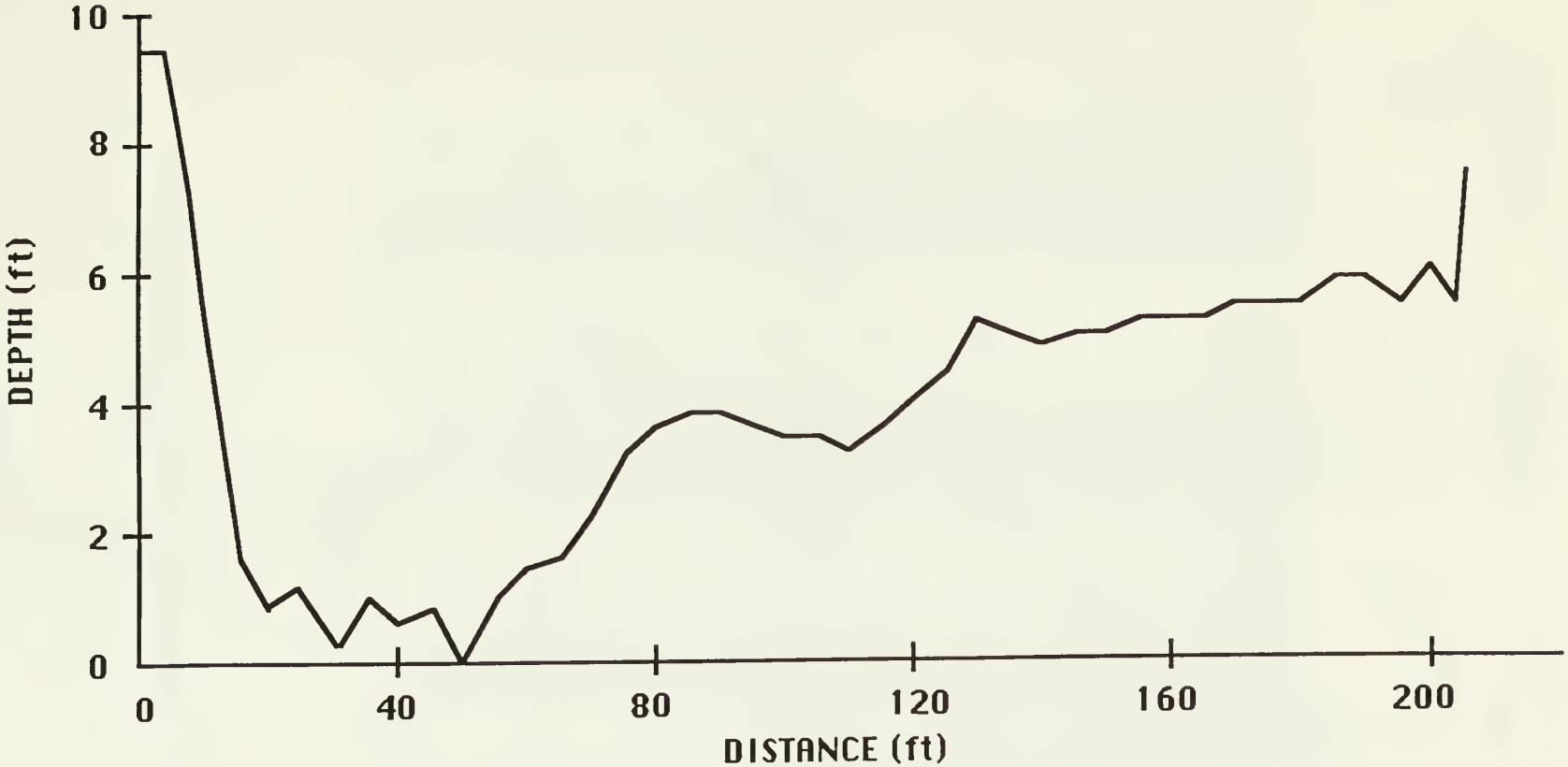
ABOVE ENTRY LOW PT	TAPE DIST	FORESIGHT OR VERTICAL DIST	CORRECTED HORIZONTAL DIST	ELEV. X-SECT
1	0.	6.000	0.	9.400
2	3.500	6.000	3.500	9.400
3	9.000	8.200	9.000	7.200
4	10.000	10.000	9.999	5.400
5	15.000	13.700	14.999	1.700
6	20.000	14.600	19.999	0.800
7	25.000	14.300	24.999	1.100
8	30.000	15.200	29.998	0.200
9	35.000	14.400	34.998	1.000
10	40.000	14.800	39.998	0.600
11	45.000	14.600	44.998	0.800
12	50.000	15.400	49.997	0.
13	55.000	14.400	54.997	1.000
14	60.000	13.900	59.997	1.500
15	65.000	13.800	64.997	1.600
16	70.000	13.300	69.996	2.100
17	75.000	12.200	74.996	3.200
18	80.000	11.700	79.996	3.700
19	85.000	11.600	84.996	3.800
20	90.000	11.600	89.995	3.800
21	95.000	11.700	94.995	3.700
22	100.000	12.000	99.995	3.400
23	105.000	12.000	104.995	3.400
24	110.000	12.100	109.994	3.300
25	115.000	11.800	114.994	3.600
26	120.000	11.400	119.994	4.000
27	125.000	10.900	124.994	4.500
28	130.000	10.300	129.993	5.100
29	135.000	10.500	134.993	4.900
30	140.000	10.600	139.993	4.800
31	145.000	10.400	144.992	5.000
32	150.000	10.300	149.992	5.100
33	155.000	10.200	154.992	5.200
34	160.000	10.200	159.992	5.200
35	165.000	10.200	164.991	5.200
36	170.000	10.000	169.991	5.400
37	175.000	10.000	174.991	5.400
38	180.000	10.000	179.991	5.400
39	185.000	9.500	184.990	5.900
40	190.000	9.500	189.990	5.900
41	195.000	10.000	194.990	5.400
42	200.000	9.400	199.990	6.000
43	203.000	9.900	202.989	5.500
44	206.000	8.100	205.989	7.300

Rating Table, Geom 9:

STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.000	0.012	0.000	0.011	0.000	0.011
0.522	1.546	0.720	2.147	9.828	0.219	3.805
1.044	14.372	1.046	13.734	35.886	0.383	5.412
1.565	56.546	1.612	35.073	47.919	0.732	47.490
2.086	132.956	2.133	62.336	55.974	1.114	55.380
2.607	244.821	2.660	92.045	59.351	1.551	58.530
3.129	384.688	3.118	123.357	62.653	1.969	61.603
3.650	477.942	2.967	161.110	88.194	1.827	67.132
4.171	661.129	3.075	214.997	111.518	1.928	110.047
4.693	956.785	3.494	273.874	117.314	2.335	115.643
5.214	1136.357	3.331	341.156	156.966	2.173	155.087
5.735	1500.432	3.495	429.286	183.755	2.336	181.475
6.256	2024.650	3.828	528.894	197.511	2.678	194.726
6.778	2700.404	4.282	630.704	199.121	3.167	195.885
7.299	3449.850	4.706	733.127	200.884	3.650	197.236

Channel Geometry, Geom-9:

CROSS SECTIONAL AREA =	733.127	SQ FEET
WETTED PERIMETER =	200.884	FEET
HYDRAULIC RADIUS =	3.650	FEET
GRADIENT =	0.0030	FEET/FOOT
MANNINGS N =	0.041	
MAXIMUM DEPTH =	7.299	FEET
MEAN DEPTH =	3.717	FEET
TOP WIDTH =	197.236	FEET
MEAN VELOCITY =	4.706	FEET/SEC
DISCHARGE =	3449.850	CUBIC FEET/SEC

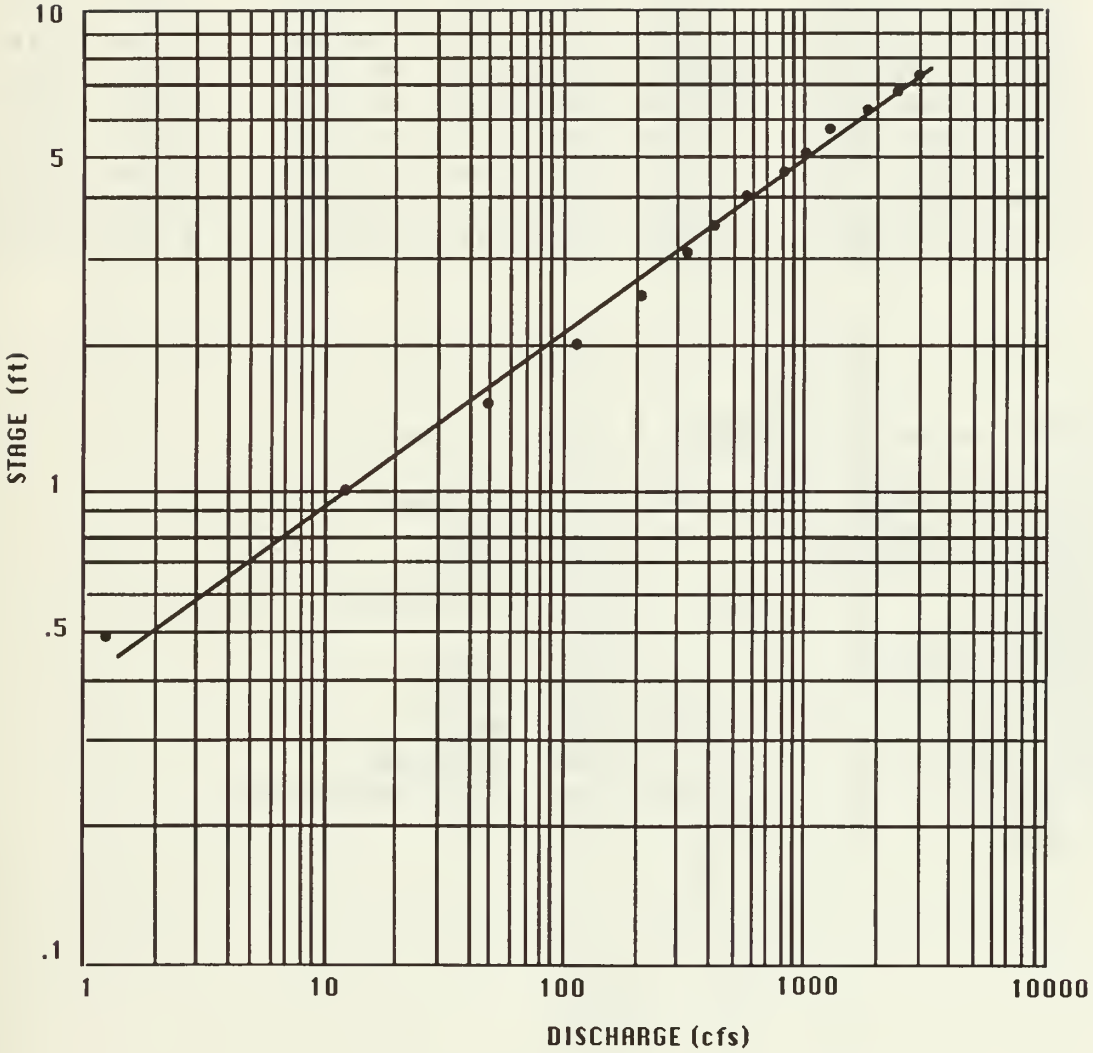


CHANNEL CROSS SECTION, BEAVER CREEK - GEOM 9

Beaver Creek, CHANL Program: selected output
Geom-10

Cross Section Data:

ABOVE ENTRY LOW PT	TAPE DIST	FORESIGHT OR VERTICAL DIST	CORRECTED HORIZONTAL DIST	ELEV. X-SECT
1	0.	4.400	0.	8.600
2	18.000	9.300	17.999	3.700
3	25.000	10.000	24.999	3.000
4	35.000	11.500	34.998	1.500
5	45.000	12.000	44.998	1.000
6	65.000	13.000	64.997	0.
7	85.000	12.700	84.996	0.300
8	105.000	13.000	104.995	0.
9	125.000	13.000	124.995	0.
10	145.000	13.000	144.994	0.
11	165.000	12.300	164.993	0.700
12	185.000	12.200	184.992	0.800
13	205.000	12.300	204.991	0.700
14	225.000	12.300	224.990	0.700
15	245.000	12.700	244.989	0.300
16	265.000	12.500	264.988	0.500
17	285.000	12.500	284.988	0.500
18	297.000	10.000	296.987	3.000
19	305.000	8.800	304.987	4.200
20	310.000	7.300	309.986	5.700



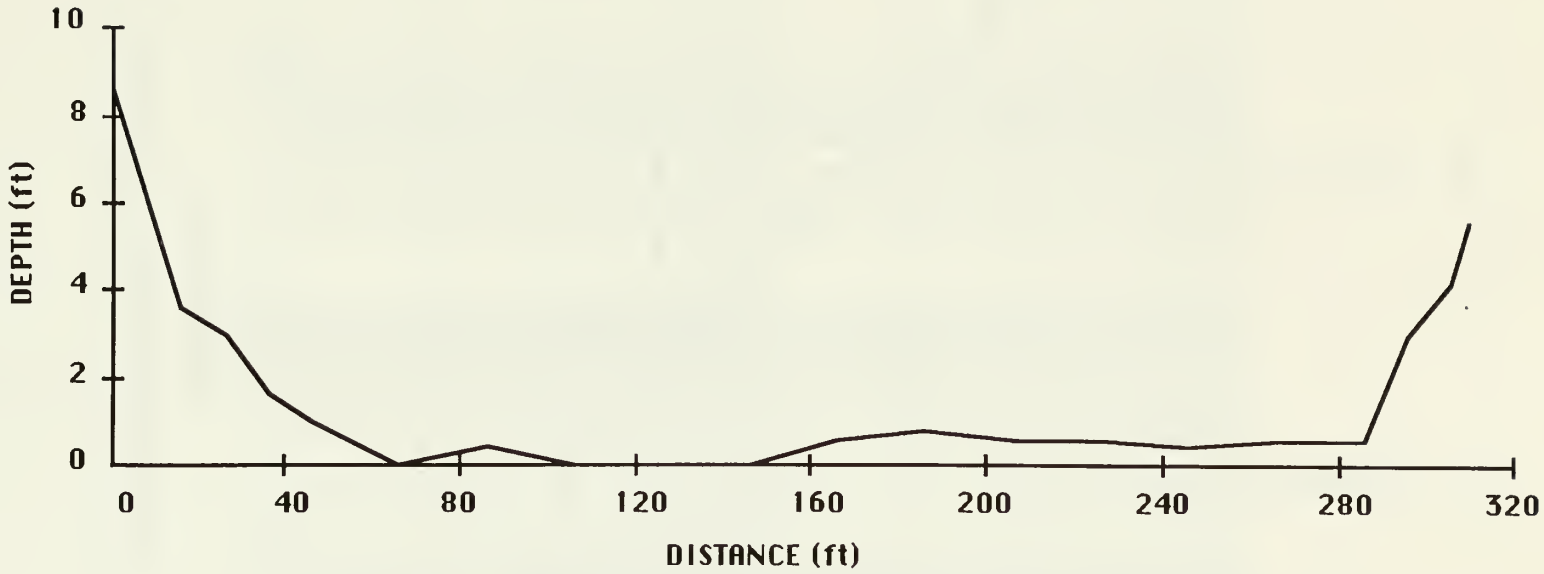
INDIRECT RATING CURVE - BEAVER CREEK, GEOM 9

Rating Table, Geom 10:

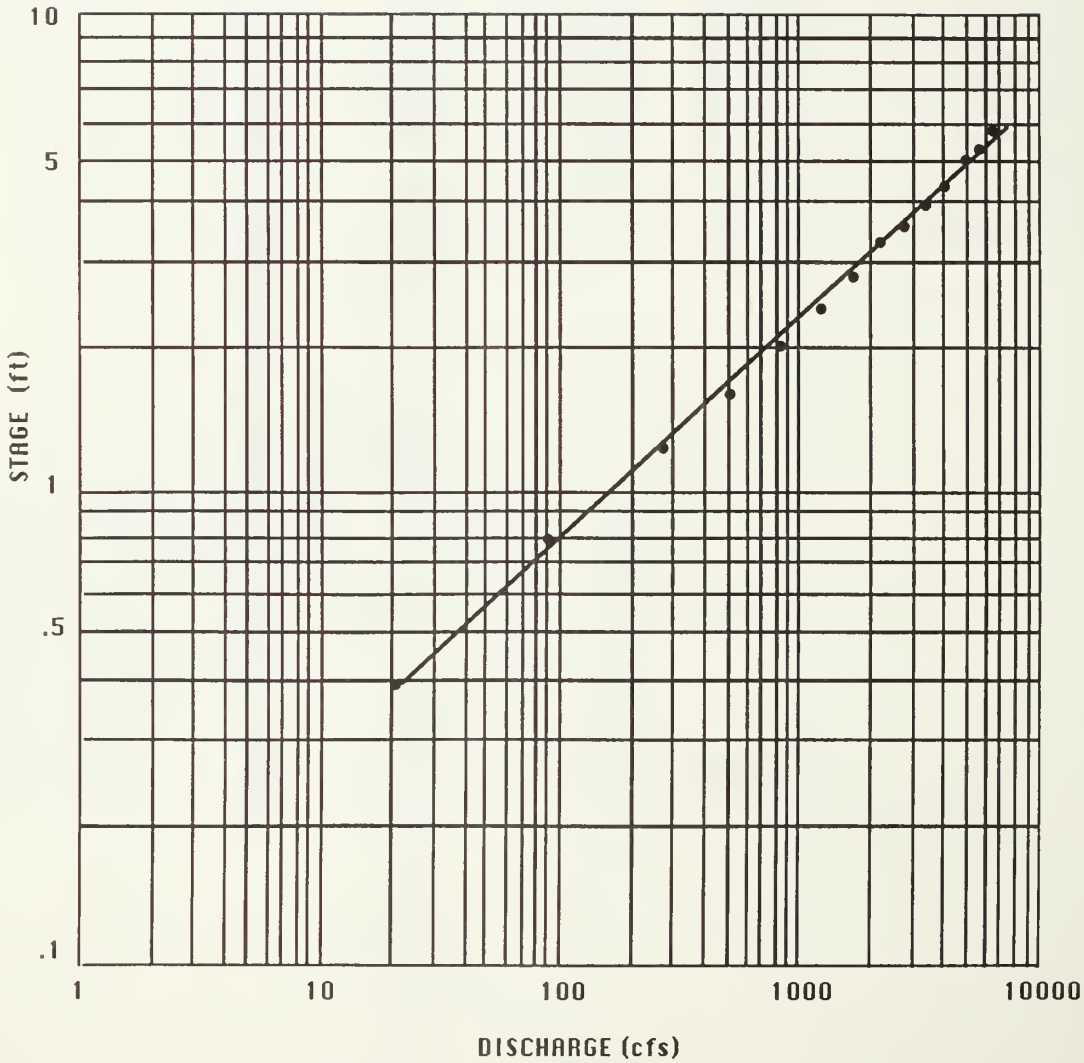
STAGE	DISCH	VEL	X-SECT AREA	WETTED PERIM	HYDR RADIUS	TOP WIDTH
0.001	0.001	0.015	0.040	40.180	0.001	0.087
0.408	19.794	0.627	31.556	116.036	0.272	99.813
0.815	85.510	0.845	101.176	237.877	0.425	237.802
1.222	258.963	1.295	200.015	248.022	0.806	247.895
1.629	505.634	1.670	302.851	256.454	1.181	256.268
2.036	821.172	2.012	408.102	261.193	1.562	260.935
2.443	1196.685	2.323	515.252	265.932	1.938	265.601
2.850	1628.635	2.609	624.302	270.671	2.306	270.268
3.257	2108.541	2.867	735.422	276.732	2.658	276.271
3.664	2636.815	3.105	849.245	283.566	2.995	283.054
4.071	3230.641	3.346	965.393	288.084	3.351	287.490
4.478	3883.281	3.585	1083.129	291.470	3.716	290.772
4.885	4588.532	3.817	1202.054	294.436	4.083	293.624
5.292	5341.879	4.040	1322.139	297.402	4.446	296.475
5.699	6142.279	4.255	1443.384	300.368	4.805	299.327

Channel Geometry, Bankfull Stage, Geom-10:

CROSS SECTIONAL AREA =	945.007	SQ FEET
WETTED PERIMETER =	287.335	FEET
HYDRAULIC RADIUS =	3.289	FEET
GRADIENT =	0.0017	FEET/FOOT
MANNINGS N =	0.041	
MAXIMUM DEPTH =	4.000	FEET
MEAN DEPTH =	3.296	FEET
TOP WIDTH =	286.756	FEET
MEAN VELOCITY =	3.305	FEET/SEC
DISCHARGE =	3123.158	CUBIC FEET/SEC



CHANNEL CROSS SECTION, BEAVER CREEK - GEOM 10



INDIRECT RATING CURVE, BEAVER CREEK, GEOM 10

PARTICLE SIZE INFORMATION - BEAVER CREEK

Size	D-16	D-50	D-85
Geom-1	23	54	92
Geom-2	29	70	105
Geom-6	19	46	66
Q-4	40	65	99
Q-6	29	58	90

Appendix C

USGS Streamgaging Proposal

United States Department of the Interior

GEOLOGICAL SURVEY

Water Resources Division
101 12th Avenue, Box 11
Fairbanks, Alaska 99701

September 24, 1986

William L. Jackson
Bureau of Land Management
Division of Resource Systems
Denver Federal Center
Bldg. 50, D-470
Denver, Colorado 80225

Dear Bill:

Enclosed are printouts of Log Pearson III Flood Frequency Analyses and daily discharge values for the period of record on Hess Creek near Livengood, and Boulder Creek near Central, Alaska.

As we have discussed over the telephone, these gaging stations are scheduled to be discontinued as of October 1, unless we can find another funding source. You have indicated the need for long-term flow information on Beaver Creek and possibly on Birch Creek. Following is a suggestion as to how this information might be obtained and at the same time continue support for the long-term gaging stations already in operation.

It would be relatively expensive to install and maintain a gaging station on Beaver Creek because the site is accessible only by helicopter. Hess Creek is a very similar basin of about 1/2 the drainage area, oriented in the opposite direction but whose headwaters lie just across the divide of the same mountains that Beaver Creek drains. Boulder Creek is much smaller than Beaver Creek, but is oriented in the same direction. Utilizing the records for these two stations and the continued operation of these sites as daily flow stations, the streamflow characteristics of Beaver Creek may be estimated by various techniques with a minimum of data collection.

Data collection on Beaver Creek could be handled in two phases. Initially, assuming the continued operation of Hess Creek and Boulder Creek gages, monthly visits would be made to Beaver Creek in the first year. Discharge measurements would be made each month, a crest-stage

gage installed, and a stage-discharge relation developed. These monthly measurements would be compared to mean daily flows at Hess and Boulder Creeks to estimate monthly and annual flow for Beaver Creek. If necessary, additional years of monthly measurements might be considered. However, probably just the operation of the crest-stage gage for annual peaks and an annual summer base-flow determination in concert with the daily flow records at Hess and Boulder Creeks would be sufficient to estimate reasonably well the open-water streamflow characteristics at Beaver Creek. Over a ten year period, we should be able to characterize the monthly and annual streamflow of Beaver Creek quite well, and the several measurements a year will provide long-term data on channel geometry changes if we establish a standard cross section for measuring. The winter measurements in the first year would give us a good idea of winter flow, but estimating winter flow in the following years would, of course, require some additional measurements. These are not included in the following cost estimates.

The first year cost to install and operate a recording gage on Beaver Creek would be about $50,000. Annual operation costs of a recording gage in subsequent years would be about $25,000. Costs for one year of monthly flow measurements, installation of a crest-stage gage, and data analysis would be approximately $30,000. Subsequent years operation for the open-water season would cost approximately $8,300, assuming three visits: one each in spring, midsummer, and late fall.

Fiscal Year 1987 operating costs for the gaging station at Hess Creek would be $15,000; Boulder Creek would cost $12,000. Total cost then for the two existing stream gages and a program of monthly measurements and peak flow on Beaver Creek would be $57,000, as opposed to $50,000 for just the installation and operation of a gaging station on Beaver Creek alone and no continued data collection on Hess or Boulder. Costs in subsequent years for all three would equal $35,300, or $10,300 more than operating just the Beaver Creek gage.

We think this proposed plan represents a good alternative to a new gage on Beaver Creek, and at the same time supports the ever shrinking gaging station network which so many depend upon for hydrologic information. However, if you require the daily discharge data that would be provided by a continuous-recording gage on Beaver Creek, we can certainly install and operate such a station.

In your plan for field studies, you indicate using data from a gage on Birch Creek to estimate streamflow characteristics for Beaver Creek. Data from this addtional gage would certainly improve any regional analysis of streamflow because Birch Creek is very similar to Beaver Creek in drainage area and orientation. We estimated costs for this gage for Larry Knapman of your Fairbanks office last year. Installation and first year operation would be approximately $35,000. Annual operation and maintenence would be about $15,000, with some increase for inflation each year.

As I indicated to you when we last talked, we would be glad to provide a review of your final report on the Beaver Creek Instream Flow Study. Please route it to Philip Emery, District Chief, U.S. Geological Survey, Water Resources Division, 4230 University Drive, Suite 201, Anchorage, Alaska 99508-4664.

If you have any questions regarding this proposal please call me at FTS (907) 456-0214, or Philip Emery at (907) 271-4138.

Sincerely yours,

Robert L. Burrows

Robert L. Burrows
Subdistrict Chief

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. BLM/YA/PT-87/014+7200	2.	3. Recipient's Accession No.

4. Title and Subtitle
Water Rights Assessment for Beaver Creek National Wild River, Alaska

5. Report Date
June 1987

6.

7. Author(s) Bruce Van Haveren, William Jackson, Tony Martinez
Bo Shelby, Lou Carufel

8. Performing Organization Rept. No.
P-248

9. Performing Organization Name and Address
U.S. Department of Interior
Bureau of Land Management
Service Center
P.O. Box 25047
Denver, Colorado 80225-0047

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address
U.S. Department of Interior
BLM Alaska State Office
701 C Street Box 13
Anchorage, Alaska 99513

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

Beaver Creek, a tributary to the Yukon River, was designated a National Wild River by Congress December 2, 1980. Inclusion into the Wild and Scenic Rivers System was based on primitiveness, exceptional grayling fishing and aesthetic qualities, abundant wildlife in the river corridor, outstanding novice and family canoeing opportunities, good water quality, and the ability of the river to provide outstanding recreational opportunities.

Based on the language in the Wild and Scenic Rivers Act (P.L. 90-542) and existing case law, a Federal reserved water right sufficient to serve the purposes of the wild river designation was created on the date Congress designated Beaver Creek a National Wild River.

The goal of this project was to identify the minimum amount of water necessary to preserve and protect the natural values of the Beaver Creek National Wild River and its immediate corridor environs and to recommend a legal vehicle through which those recommended flow regimes can be recognized and protected.

17. Document Analysis a. Descriptors

0504 Water rights
0504 Stream flows
0504 Water law
0808 Rivers

b. Identifiers/Open-Ended Terms

National Wild River
Beaver Creek National Wild River
Wild and Scenic Rivers System
Alaska

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release Unlimited	Unclassified	232
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

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